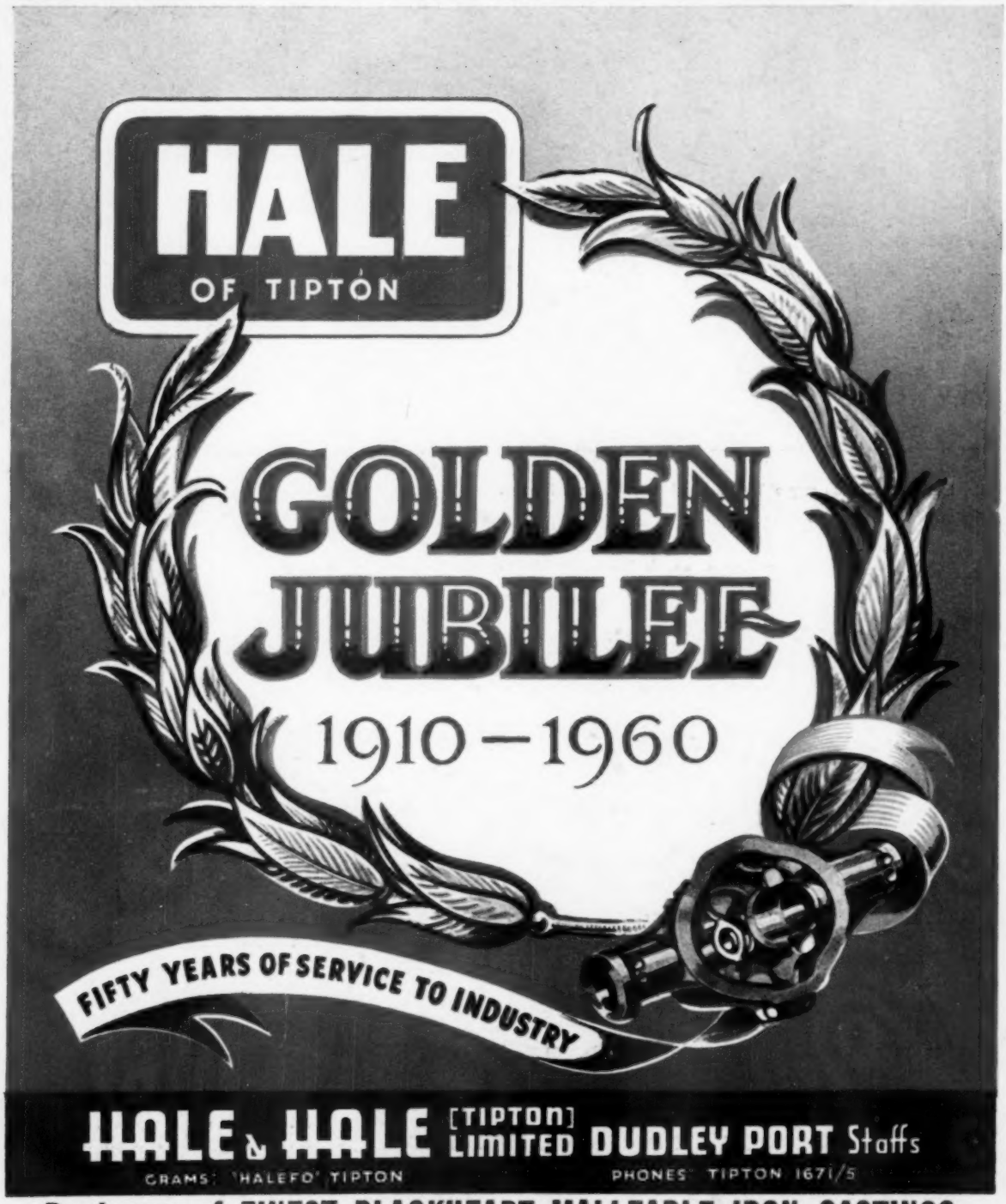
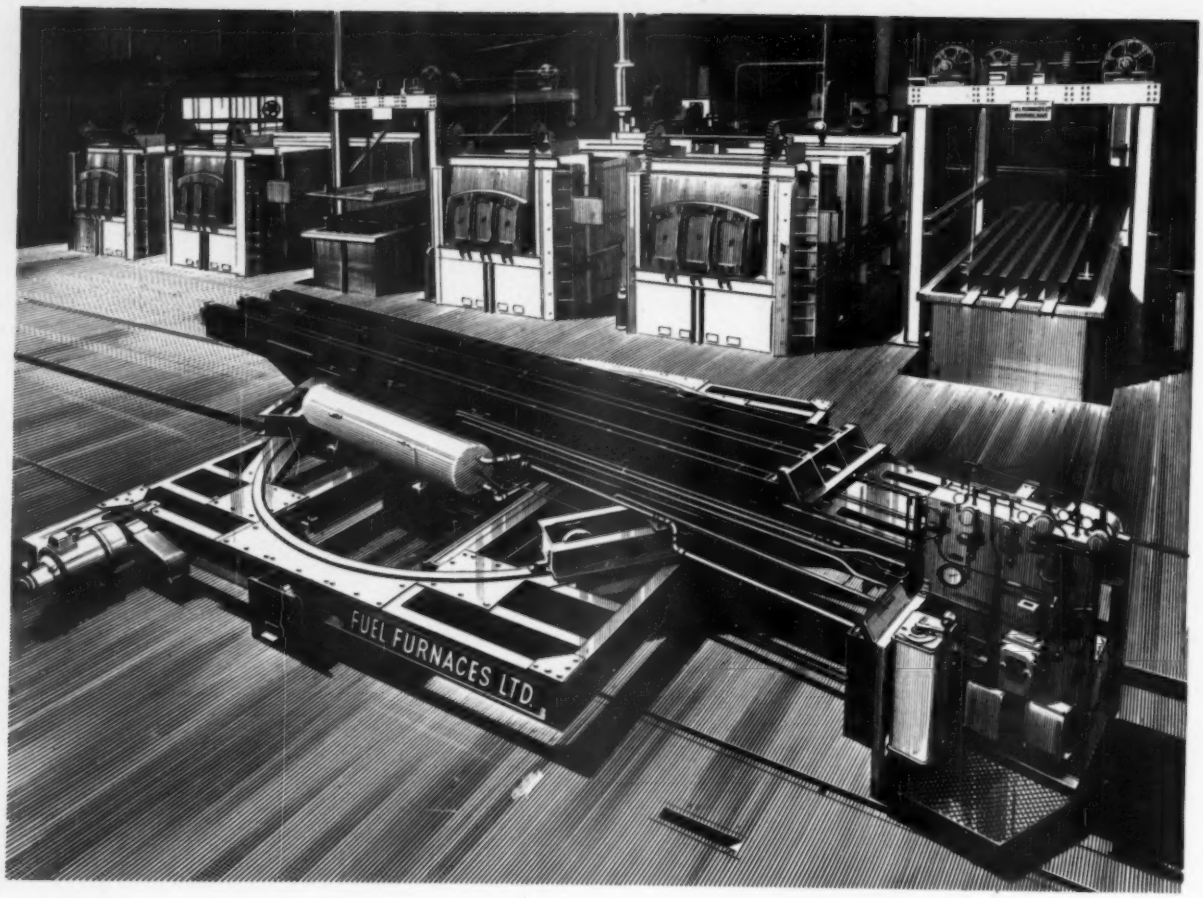
METALLURGIA

THE BRITISH JOURNAL OF METALS

Vol. 62 No. 372 OCTOBER, 1960 Monthly: Two Shillings and Sixpence



Producers of FINEST BLACKHEART MALLEABLE IRON CASTINGS



Impression by courtesy of The Kirkstall Forge Engineering Ltd.

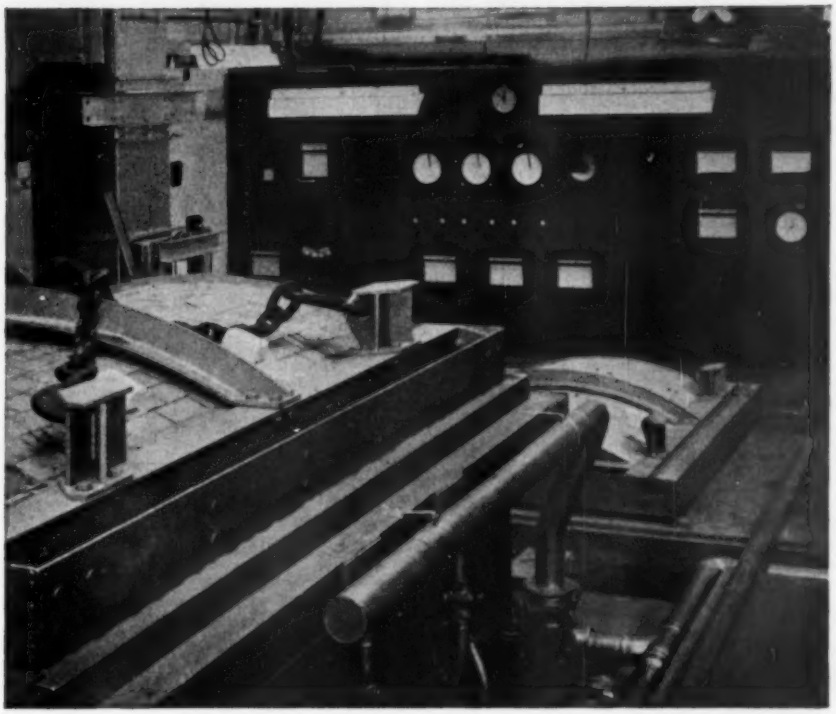
heat treatment of steel bars and coils

high velocity recirculating atmosphere

FUEL FURNACES LTD.

Shady Lane Great Barr Birmingham 22A

Experimental Batch Furnace
fully instrumented



B.I.S.R.A. begin a new chapter in research with their new experimental forge furnace. It will give the steel industry the answers to many long-standing questions on furnace design, operation and control

The Energy Section of B.I.S.R.A. is now studying how to improve efficiency in batch type heating processes. And Honeywell Instrumentation is helping to write up the essential facts and figures —programming the heating cycles, too.

MULTI-RECORDING. Four ElectroniK 12-point Recorder/Controllers continuously record the data from more than 100 thermocouples dispersed in the walls, chamber, flues, air ducts, recuperator, stack of the new experimental forge furnace, and in the 3-ton ingot.

PROGRAMME CONTROLLING. A master temperature Controller sets the heating cycle and governs secondary controllers for fuel flow. At the same time, other Honeywell instruments keep a critical eye on furnace pressure, or help the analysis of flue gases.

BIOGRAPHICAL NOTE. Similar instruments are used throughout B.I.S.R.A's laboratories. Versatile, accurate, they are adaptable to pure research, pilot plant operation and to process control on the largest scale. In every application they are made doubly valuable by the design, engineering and maintenance service they carry with them from Honeywell Head Office or from branches in the principal towns and cities in tne United Kingdom.

I am interested in applying Honeywell Instruments to _____ *(state application)*

Please send me technical information ☐

Please ask your engineer to call ☐
(tick where applicable)

Name _____

Position _____

Company _____

Address _____

_____ M

WRITE OR SEND THE COUPON TODAY to:
Honeywell Controls Limited, Ruislip Road East, Greenford, Middlesex. Waxlow 2333

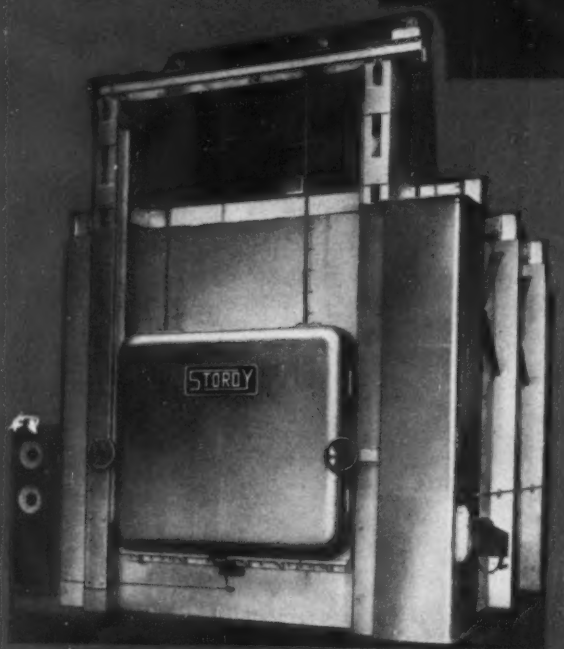
Honeywell

First in Control

SINCE 1885

STORDY

HEAT TREATMENT FURNACES



The range of Stordy heat treatment furnaces include batch, pit and continuous types, heated by oil, gas or electricity, with indirect firing when required. The Stordy system of forced air circulation is unique in its efficiency and in providing rapid heating up rates and uniform heating conditions throughout the chamber with maximum fuel economy.

Stordy heat treatment plant includes all the necessary materials handling equipment—robust charging and discharging machine conveyors, transfer tables, loading and unloading racks.

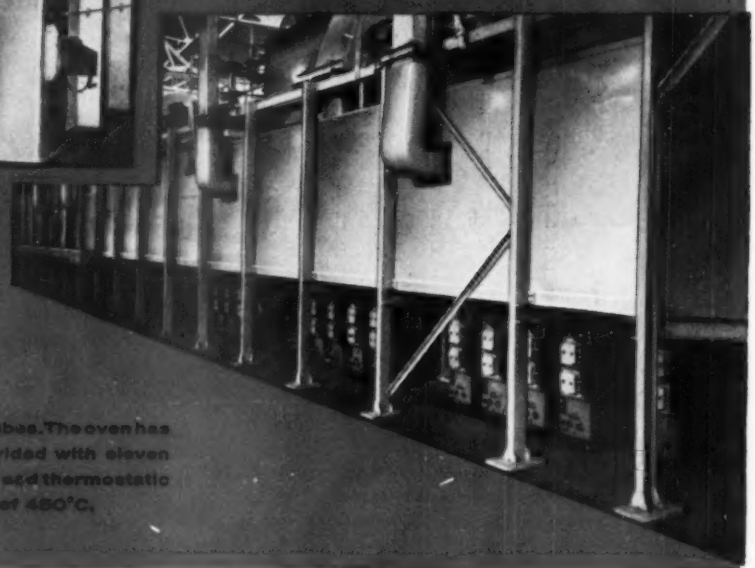
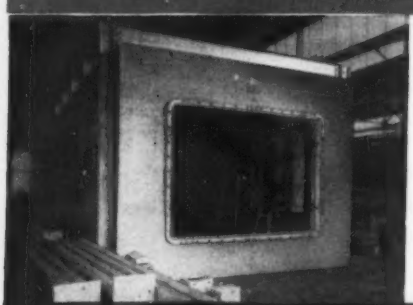


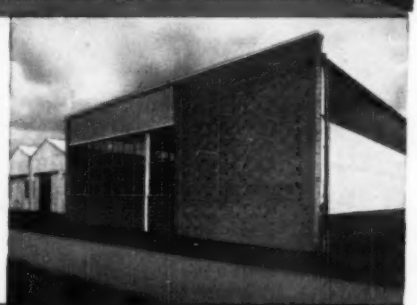
Illustration above: Electrically heated, air circulated batch-type furnace for aluminium. Working temperature 600°C, the furnace being complete with electric heater batteries and circulating fans, designed for ease of removal. Illustration right: High temperature heat treatment oven for television tubes. The oven has a heated length of 200' 0", being provided with eleven combustion chambers, circulating fans and thermostatic controls for a maximum temperature of 450°C.



DESIGNED AND FABRICATED BY

STORDY

Stordy have full manufacturing facilities at their new Wombourn Works and design staff, technical and service engineers in the field combine to provide a completely integrated furnace design and building service.



STORDY ENGINEERING LIMITED

CUMBRIA HOUSE SEDGTHORN HILL WOLVERHAMPTON Telephone Wolverhampton 27557

SM/SE6124

NICHROME V, NICHROME,* CHROMAX* BY* BRITISH DRIVER-HARRIS

Of the products we make, the Nichrome series of alloys is pre-eminent. The name Nichrome is registered as a Driver-Harris trade mark in some sixty countries. It is accredited the world's standard of quality for electrical resistance heating. Nichrome V and Nichrome (the two alloys in most demand today) were not perfected overnight. They have been developed over generations. We take care that this hard-won knowledge is worthily supported in the process of manufacture. At every stage quality is severely controlled and checked. The key craftsmen have many years' experience, and they have the use of impeccable equipment.

Nichrome* V is a nickel-chromium alloy of the 80/20 type. It is used for high temperature resistance heating applications at temperatures up to 1150°C. For resistor elements in such as electric furnaces, domestic cookers and fires, it is ideal. It can be supplied in wire, hot and cold rolled strip, hot rolled rounds, and ribbon form. It is also available in superfine sizes—.002 in. (0.05 mm.) downwards for applications like precision resistors in electronic equipment, and where high ohmic value is necessary.

Nichrome* is a nickel-chromium alloy of the 65/15 type. It is the accepted material for heating elements operating at temperatures up to 950°C, including all types of domestic appliances in this temperature range. It is also used for rheostat and resistance units. It makes for compact units capable of withstanding severe overloads and short circuits without damage or impairing circuits. It resists corrosion and has many non-electrical applications. It is available in the forms of wire, hot and cold rolled strip, hot rolled rounds, and ribbon. Also in superfine wire sizes.

Chromax* This alloy has the nominal composition 37% nickel, 18% chromium, balance iron. It has been developed for use in furnace elements, and particularly for carburising atmospheres.

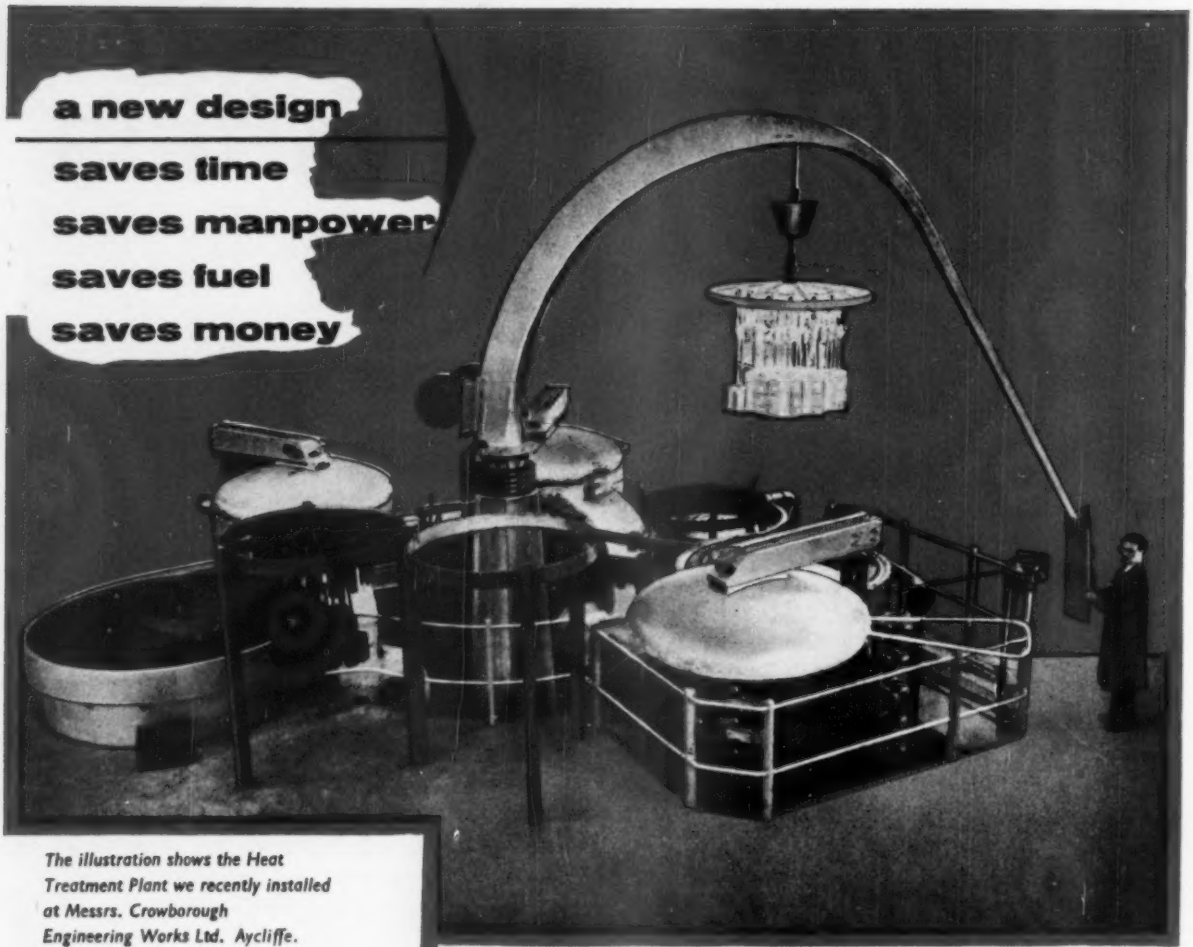
For further information on Nichrome V and Nichrome, write for Data Sheet No. 5—a 24-page booklet.

*REGD. TRADE MARK

BRITISH DRIVER-HARRIS CO LTD

Cheadle Heath, Stockport, Cheshire

COMPLETE
HEAT TREATMENT PLANT



The illustration shows the Heat Treatment Plant we recently installed at Messrs. Crowborough Engineering Works Ltd. Aycliffe.

The complete unit installation at Aycliffe consists of Hardening Furnace, two Tempering Furnaces, Water Quench Tank, Oil Quench Tank, Loading and Unloading Racks. The unit is serviced by a fully-automatic, centrally-located, electrically-operated crane. The two re-circulating Tempering Furnaces utilise the waste heat from the Hardening Furnace. Supplementary gas is automatically provided when necessary.

Further details are available on enquiry to :—

STERLING FURNACES LIMITED

13, Marton Road, MIDDLESBROUGH

Telephone : **43328.** *Telegrams : Sterling, Middlesbrough*

Advanced techniques
and reliable service
have established for
Smethwick Drop Forgings
a fine reputation

The stamp of quality

SDF

SMETHWICK DROP FORGINGS LTD · SMETHWICK & KIDDERMINSTER

Severn

MICROFIN
DIAMOND ABRASIVE COMPOUND FOR METALLOGRAPHY

●Microfin Diamond Abrasive Compound is made in both water and oil soluble composition. Used for polishing Metallurgical specimens it is helping laboratory practice by bringing out the metal's pure characteristics without causing metal flow and by giving clear definition of grain boundaries edges and inclusions.

USED IN MODERN METALLURGICAL LABORATORIES AT HOME AND OVERSEAS

Our TECHNICAL SERVICE will be pleased to arrange a demonstration in your own laboratories

UNIVERSAL DIAMOND CO. LTD.

Unidiac Works, 192 Seven Sisters Road, LONDON, N.4 Telephone and Telegrams: ARCHway 0116/7

HIGH CAPACITY WIRE PATENTING FURNACE

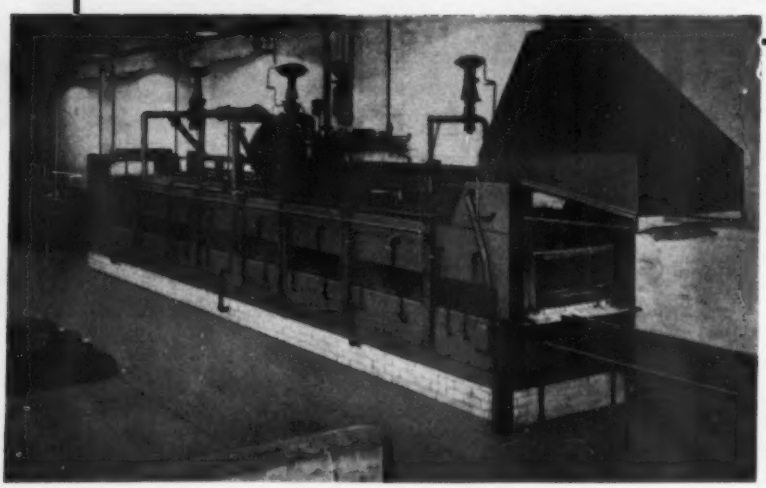


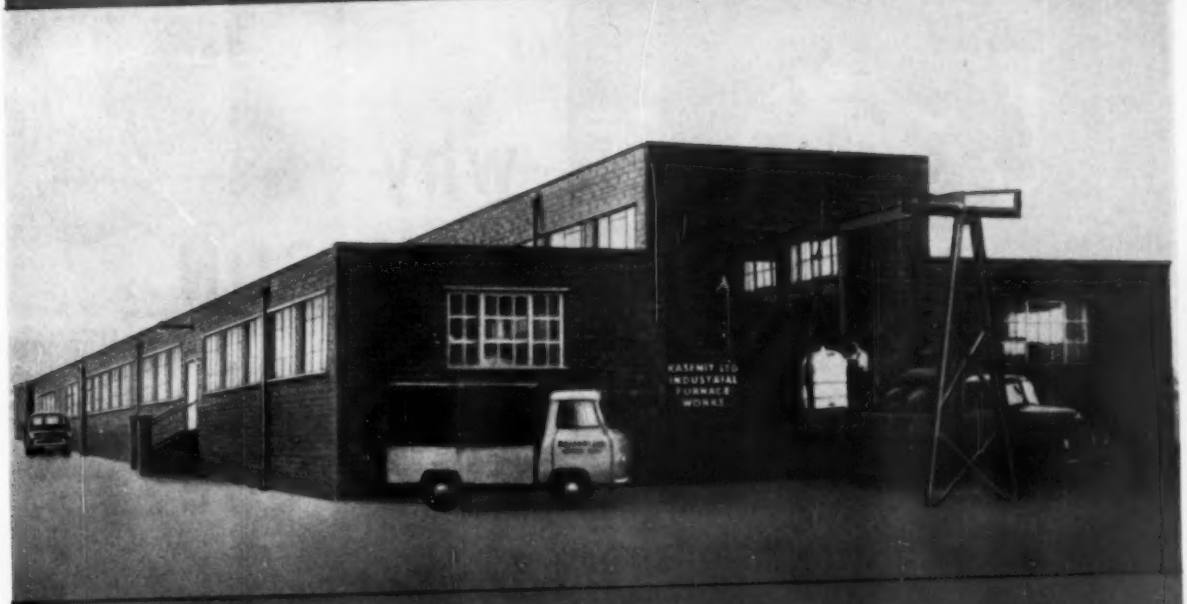
Illustration by courtesy of
FREDERICK SMITH & CO.
(Wire Manufacturers) LTD. HALIFAX.

Improved physical properties, dependable uniformity, cleaner surface of the wire, in addition to lower operating costs per ton, are obtained with Dowson & Mason Furnaces.

DOWSON & MASON MANUFACTURE—
Galvanising Tinning & Lead Bath Furnaces;
Wire and Rod Baking Ovens;
Bell type Bright Annealing Furnaces.

DOWSON & MASON LTD
ALMA WORKS LEVENSHULME MANCHESTER
Telephone: HEATON MOOR 4151 (5 lines) Telegrams: Gaslit, Manchester 19
D·G·I GROUP

OUR NEW FACTORY AT BLETCHLEY



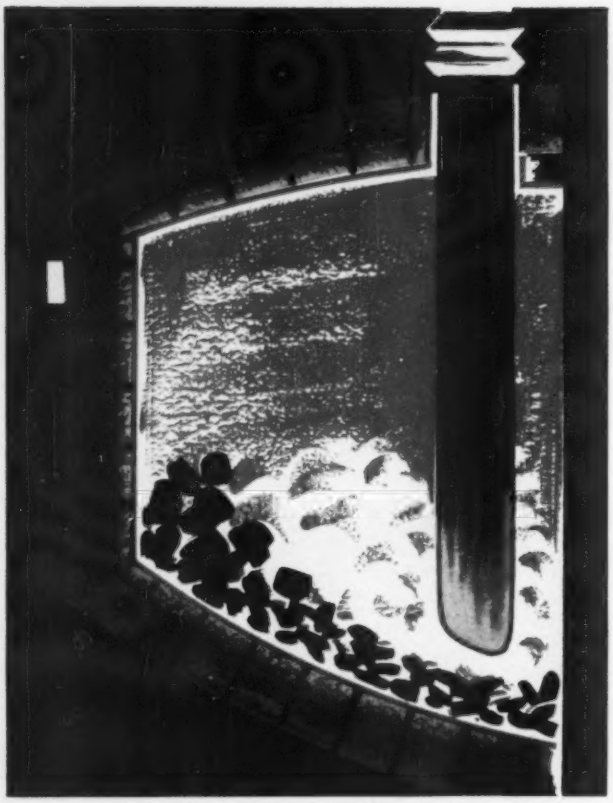
● To increase our output of Industrial Furnaces we have acquired a modern Factory in Bletchley, Buckinghamshire, to which we have transferred the Furnace building side of our business.

The Factory covers an area of some 15,000 sq. ft. and we can therefore now handle much larger Furnaces than before. The Works has been equipped with up-to-date Machine Tools, and we have excellent loading and unloading facilities which include an overhead runway with an electric lifting block of 5-tons capacity.

We carry a wide range of refractories which enables us to handle urgent repair work and give prompt delivery for new equipment. We shall be pleased to receive enquiries for Gas, Oil and Electric Furnaces, Salt Baths, Air Circulators, etc.

KASENIT LTD

7, Hatherley Grove, Bermondsey, London, S.E.1.



why ACHESON TRADE MARK graphite electrodes

Give You Dependable Service!

" Acheson " Graphite Electrodes are manufactured from specially selected high grade raw materials which are carefully processed at all stages of manufacture under controlled conditions to give a final electrode for your arc furnaces with these properties at their optimum—

LOW RESISTANCE

HIGH MECHANICAL STRENGTH AT OPERATING TEMPERATURES

EXCEPTIONAL THERMAL SHOCK RESISTANCE

" Acheson " Graphite Electrodes are made in the United Kingdom only by

BRITISH ACHESON ELECTRODES LIMITED of SHEFFIELD.

ACHESON

TRADE MARK

GRAPHITE ELECTRODES

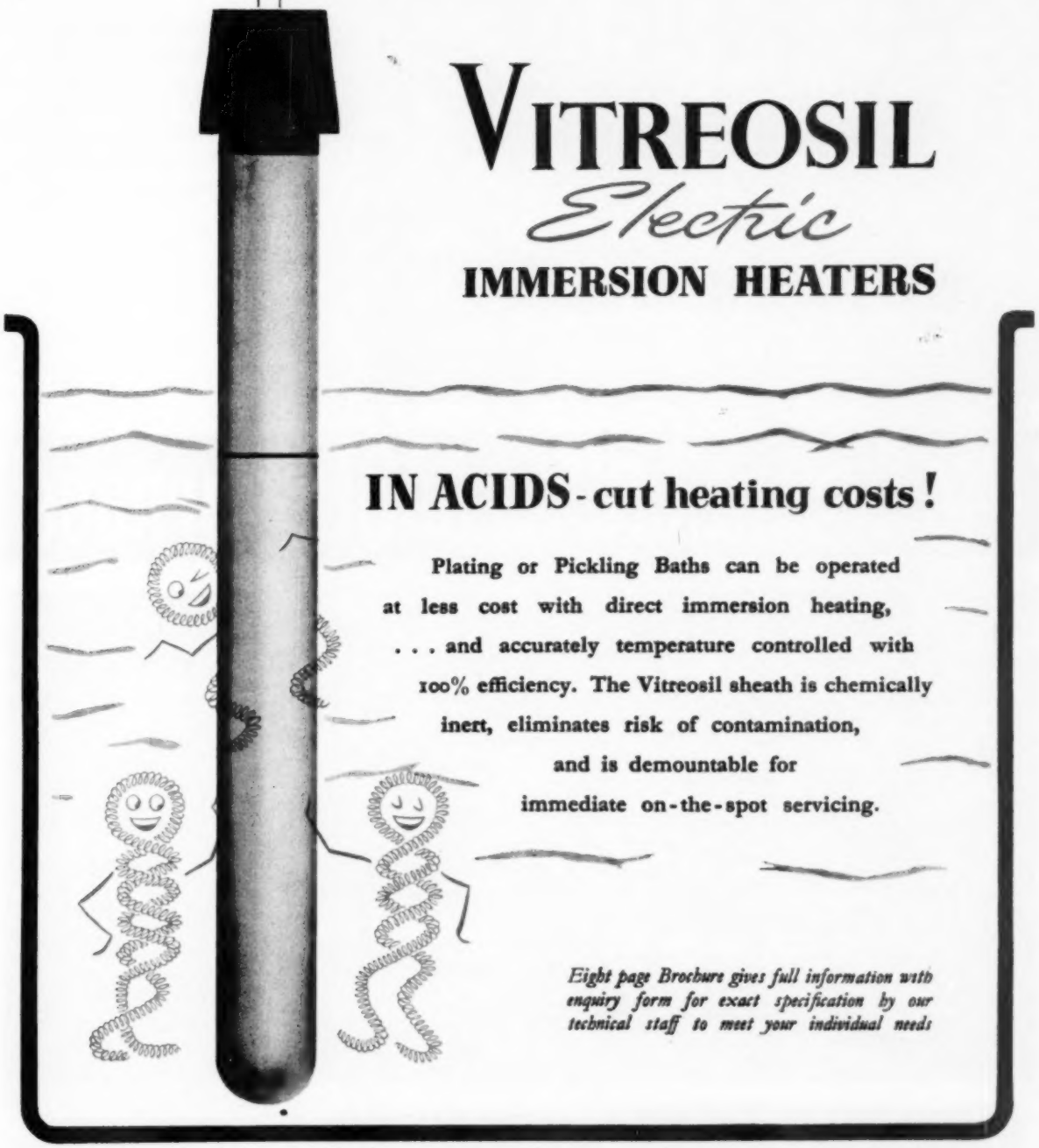
The term ACHESON is a registered trade mark

ACID – PROOF FUSED SILICA SHEATH

VITREOSIL

Electric

IMMERSION HEATERS



IN ACIDS - cut heating costs !

Plating or Pickling Baths can be operated at less cost with direct immersion heating, . . . and accurately temperature controlled with 100% efficiency. The Vitreosil sheath is chemically inert, eliminates risk of contamination, and is demountable for immediate on-the-spot servicing.

Eight page Brochure gives full information with enquiry form for exact specification by our technical staff to meet your individual needs

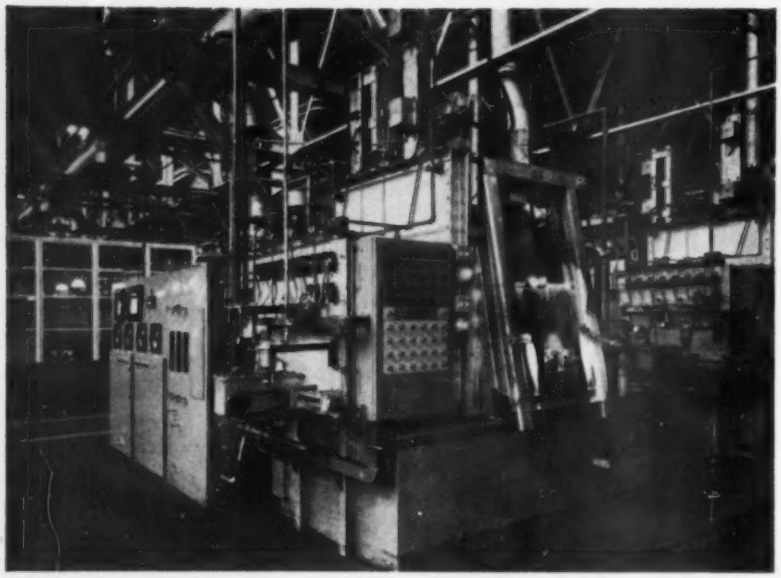
FOR ALKALIS—SPECIAL HEATERS AVAILABLE

TSL

THE THERMAL SYNDICATE LTD.

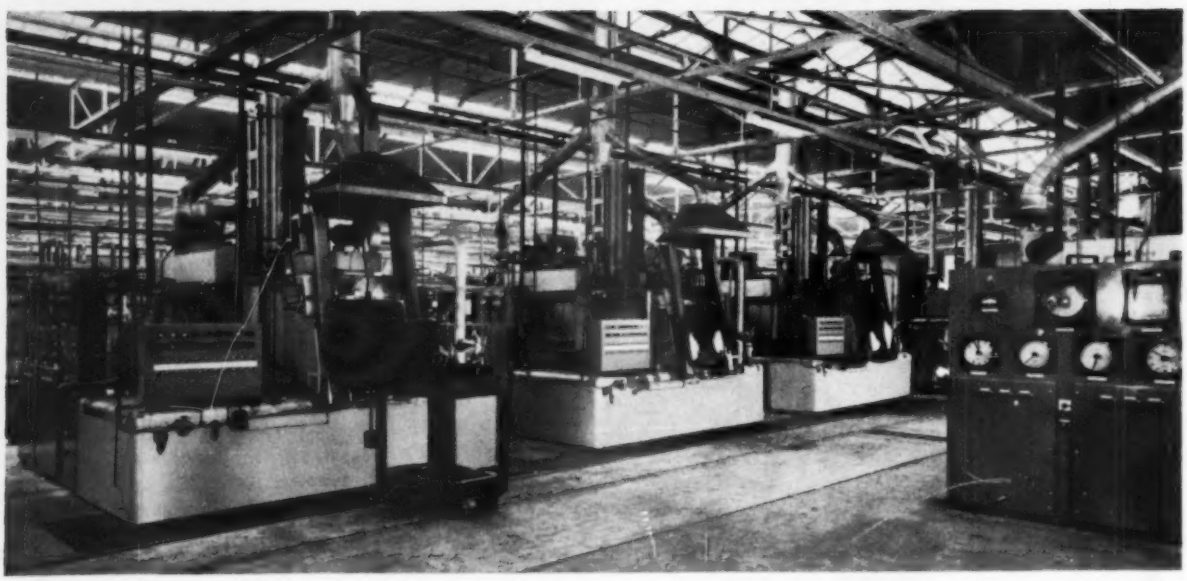
P.O. BOX No. 6, WALLSEND, NORTHUMBERLAND. *Tel: Wallsend 62-3242/3*

LONDON: 9, BERKELEY STREET, W.1. *Tel: Hyde Park 1711/2*



The 'Allcase Furnaces' illustrated forms part of a battery of fully automatic sequence and programme controlled Furnaces used for Gas Carburising, Carbonitriding, and Reheating of various automobile components.

the versatile "ALLCASE" furnace



Two 'Allcase' Furnaces at the works of a leading motor manufacturer, used for carburizing and carbonitriding steering and other parts, requiring various case compositions and depths. The hearth area of each furnace is 3′ 0″ × 2′ 0″ with 1′ 6″ permissible depth of charge, and is designed to accommodate gross charge weights varying from 900 lbs. at 750 C. to 500 lbs. at 950 C.

PROCESSES ;

With an operating temperature range of 1,400 to 1,750 F the following controlled atmosphere processes can be carried out.

1. Gas Carburizing. 2. Hot Oil Marquenching. 3. Clean Hardening. 4. Dry cyaniding or Carbonitriding. 5. Carbon Restoration. 6. Homogeneous Carburizing. 7. Clean Annealing.

BRITISH FURNACES LTD.
CHESTERFIELD
ASSOCIATED WITH SURFACE COMBUSTION CORPORATION, TOLEDO, U.S.A.

B·O·A·C takes good care of you

—with ILFORD Industrial B X-ray film

High among the priorities of BOAC is safety. Behind the scenes at London Airport is some of the world's finest equipment, operated by highly trained personnel to ensure the reliability of every detail that contributes to safe operation.

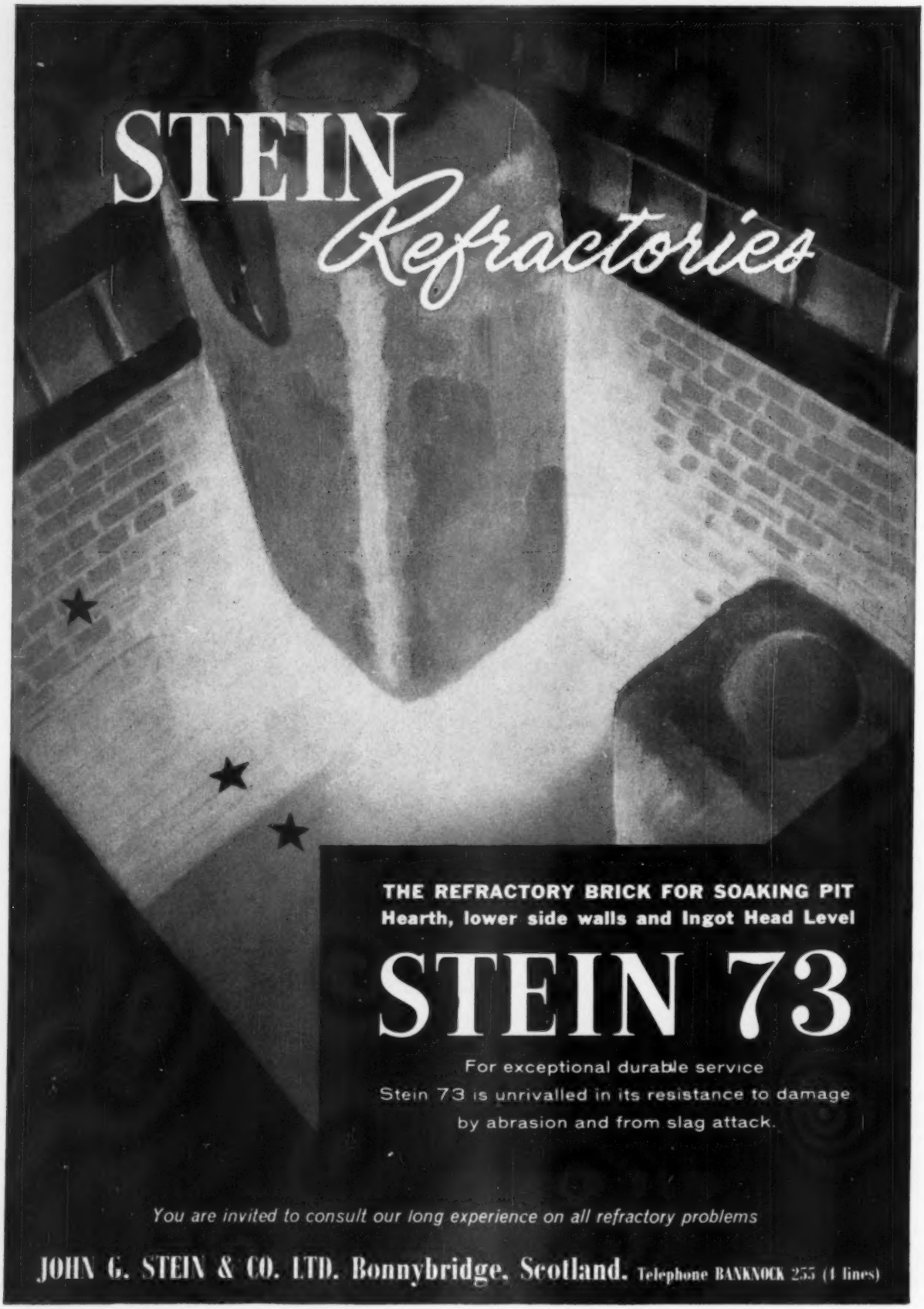
Where even the smallest foreign particle may imperil life, nothing is left to chance. Complex units, such as engine oil coolers which cannot be dismantled for inspection, are therefore radiographically examined to detect accumulations of sludge, metal debris, and carbon particles which would spell danger if they circulated in the engine lubrication system.

For this examination, British Overseas Airways Corporation relies on ILFORD Industrial B X-ray film. Ilford has a reputation for reliability.

Where reliability is all-important

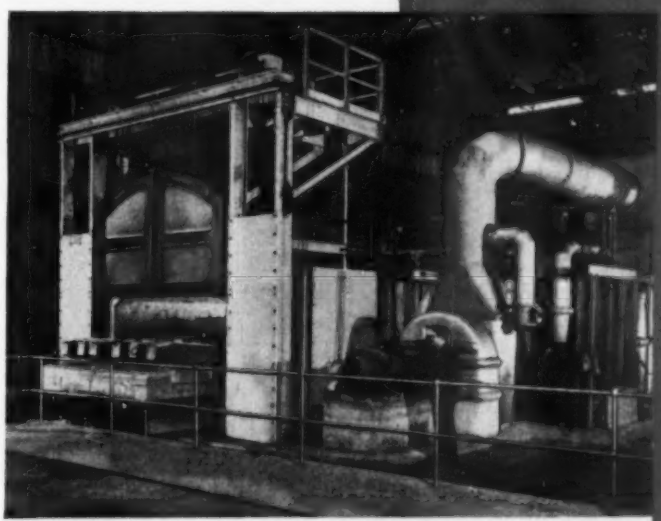
ILFORD

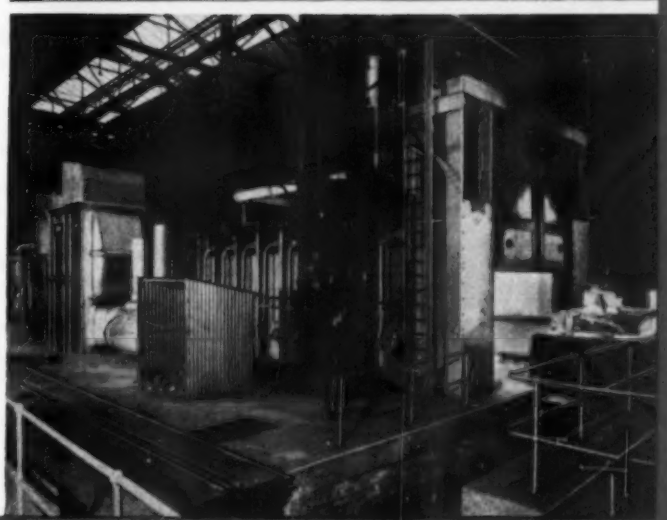
ILFORD LIMITED · ILFORD · ESSEX


STEIN
Refractories
THE REFRACTORY BRICK FOR SOAKING PIT
Hearth, lower side walls and Ingot Head Level
STEIN 73
For exceptional durable service
Stein 73 is unrivalled in its resistance to damage
by abrasion and from slag attack.
You are invited to consult our long experience on all refractory problems
JOHN G. STEIN & CO. LTD. Bonnybridge, Scotland. Telephone BANKNOCK 255 (4 lines)

PRIEST

CONTINUOUS BOGIE TYPE REHEATING FURNACE





Illustrated is a Gas-fired Furnace supplied to Jessop-Saville Ltd. Brightside Works, Sheffield, for reheating alloy steel ingots prior to rolling.

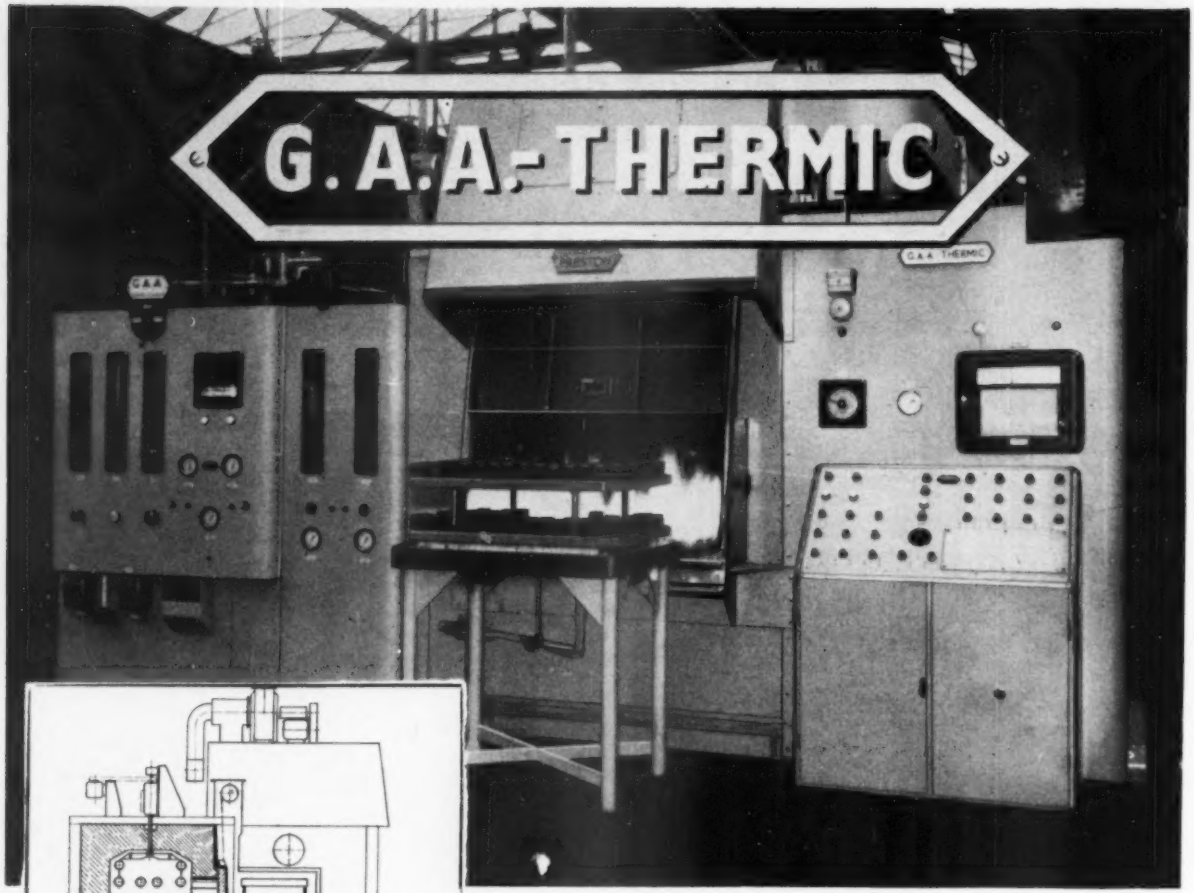
We also specialise in the design and construction of:—

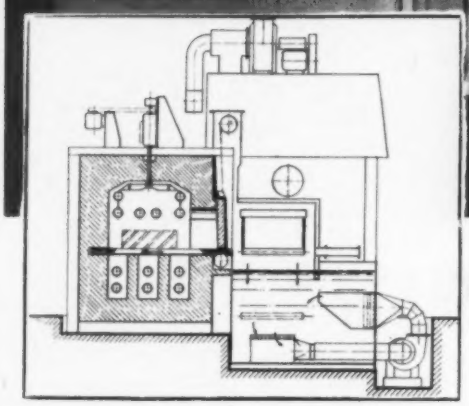
Open Hearth Furnaces
Soaking Pits of all types
Continuous Multi-zone Bloom and Slab Re-heating Furnaces
Continuous Bogie type Ingot and Slab Heating Furnaces
Furnaces for Aluminium Melting, Coil Annealing and Slab Re-heating
Forge and Heat Treatment Furnaces
Stress Relieving Furnaces
Shipyard Plate and Bar Furnaces

PRIEST FURNACES LIMITED · LONGLANDS · MIDDLESBROUGH

also at KELHAM ISLAND WORKS · SHEFFIELD 3

F.155

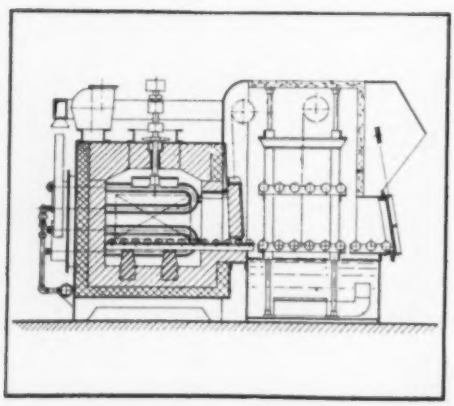




Controlled atmosphere Batch Furnaces for

CLEAN HARDENING, CARBO NITRIDING

CARBON RESTORATION, GAS CARBURISING



Alternatively Rotating Retort batch type equipment with "built-in" atmosphere control is available. Or pusher type furnaces for continuous production.

THERMIC

EQUIPMENT & ENGINEERING CO., LTD.

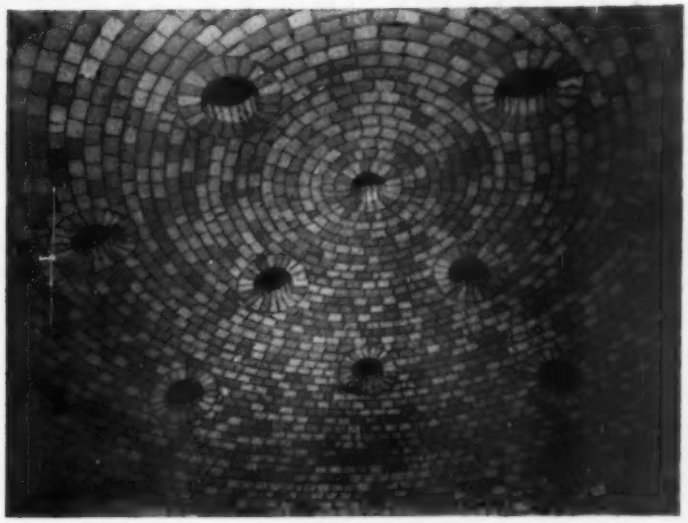
(Associated with Gibbons Applied Atmospheres Ltd., Birmingham, 15)

SALMON STREET

PRESTON

Tel. PRESTON 56254/5 ***'Grams: THERMIC, PRESTON***

We take our own medicine . . .



Five years ago we began rebuilding the round down-draught kilns of The Morgan Crucible Co. Ltd. at Battersea in MI. 28 — a hot-face insulating brick of low thermal capacity that was then comparatively new. The roof of one of these furnaces immediately after installation is shown in the first picture.

. . . (MI. 28 bricks) . . . and like it

The output of these kilns, lined with MI. 28, was considerably greater than their firebrick counterparts, because the low heat-storage of the lining shortened both heating and cooling periods. This, in fact, was the principal reason for the change-over. What we were not so sure of at that time was the life of these linings. We would hardly have dared to expect anything as good as we got. The second picture shows the same roof after *five years'* service. So far as we can see it is good for at least another five years and probably longer.

MORGAN Refractories Ltd

MORGAN REFRACTORIES LTD. NESTON, WIRRAL, CHESHIRE. TELEPHONE: NESTON 1406

NE 160A

NICKEL ALLOY STEELS

ensure reliability underground

Huwood Slicer Loader and P.80 Conveyer

Mechanised coal mining involves the use of much highly developed power-driven cutting and loading machinery. Notable producers include Hugh Wood and Co. Ltd., Gateshead, who are pioneers in this field.

In the 'Huwood' Longwall Loading Machine, nickel alloy steels are used for stressed components to ensure continued reliability in underground working. The steels used for these components include the well-known nickel-containing compositions: En23 and En25 for face loader; En24 — slicer loader and 'Python' gearbox; En33 — pneumatic pick barrels; En36 and En110 — tail shafts for PA/5, CF chain conveyors.

TYPICAL MECHANICAL PROPERTIES OF

EN23

SIZE	HEAT TREATMENT	MAXIMUM STRESS t.s.i.	ELONGATION per cent	IZOD ft. lb.
5½ in.	Oil quenched 830°C tempered at 630°C	65	19	57
2½ in.	Oil quenched 830°C tempered at 560°C	68	17	43

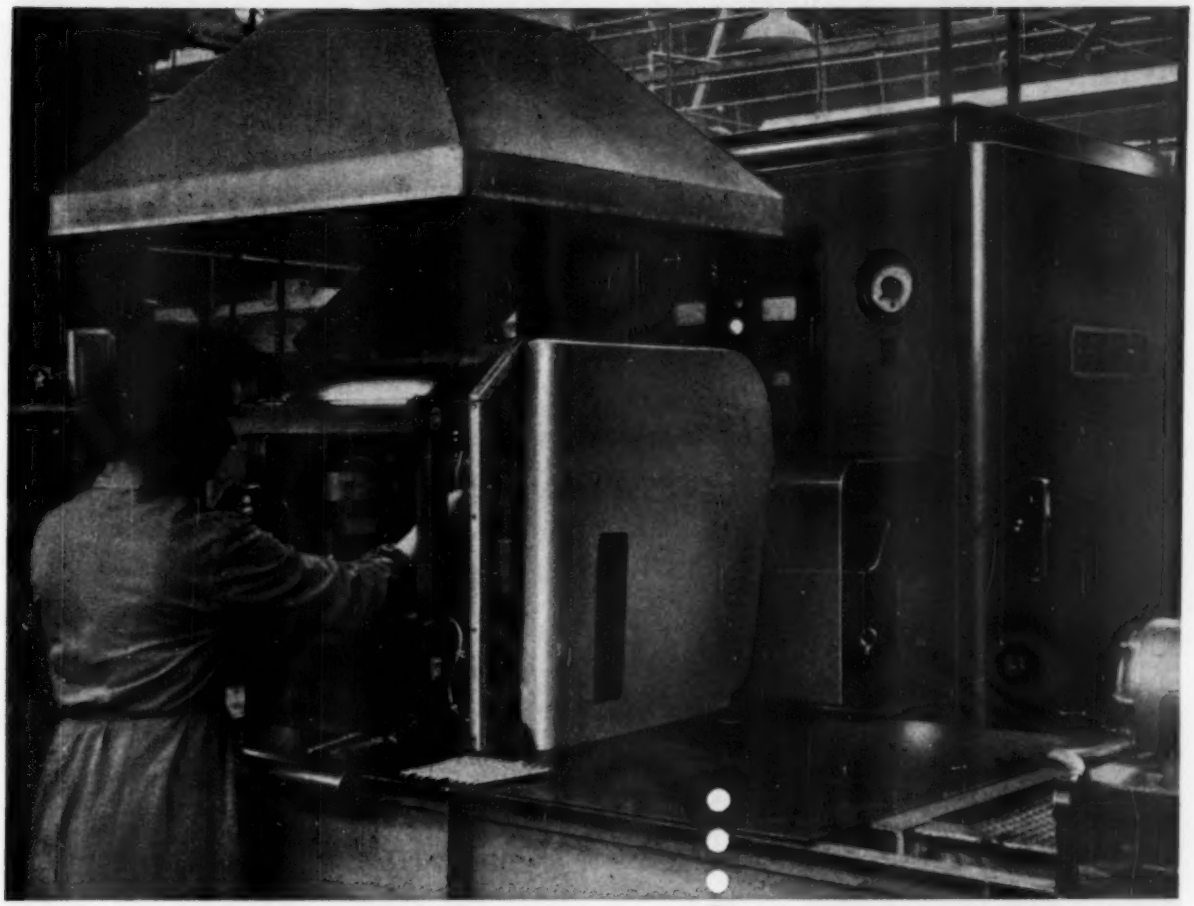
By utilising the better properties obtainable in more highly alloyed nickel steels, dimensions can be reduced, lighter constructions produced, distortion through heat treatment minimised and reliability and economy achieved.

Please send for our publications entitled, 'The Mechanical Properties of Nickel Alloy Steels' and 'The Case Hardening of Nickel Alloy Steels'

MOND NICKEL

THE MOND NICKEL COMPANY LIMITED, THAMES HOUSE, MILLBANK, LONDON, SW1

TGA 21/2/18



Wild-Barfield A.H.F. equipment is used by Wolf Electric Tools, Ltd., (manufacturers of the well-known Wolfcub drills etc.), for the hardening and tempering of small gears, shafts and pinions. Many other industrial concerns have found that Wild-Barfield A.H.F. induction heating speeds production, saves space and offers savings all along the line. Our engineers will be glad to supply further details and explain how Wild-Barfield A.H.F. equipment can help you.

WILD-BARFIELD A.H.F. equipment at WOLF ELECTRIC TOOLS LTD

WILD BARFIELD A.H.F.

Induction heating speeds production

WILD-BARFIELD ELECTRIC FURNACES LIMITED

ELECFURN WORKS, OTTERSPOOL WAY, WATFORD BY-PASS, WATFORD, HERTS. Telephone: Watford **26091** (8 lines)
WB 64

THE K.I.P. range includes lightweight insulating firebrick in 6 grades for temperatures up to 1500°C—"back-up" insulation up to 850°C and insulation castables up to 1300°C.

REFRACTORY BRICKS
POTTERY
SANITARY WARE
ENAMEL WARE
HEATING EQUIPMENT

KINGSCLIFFE
INSULATING PRODUCTS LTD.

Head Office: STORRS BRIDGE WORKS · LOXLEY · Nr. SHEFFIELD · Tel 343844-5-6

One of the MARSHALL REFRACTORIES GROUP of Companies

KIP. 31

He's a casting director of many parts . . .

. . . and the results of his work give excellent performance.

For, whatever casting process is required for *your* production — cement-sand, shell-moulding or 'lost wax' — the team of experts at David Brown Foundries Division carries it out with supreme skill and care.

There is no proven method of casting that is not within the scope of the Division's resources. There is no recognised technique of testing that is not used at Penistone. Inspection by X- and gamma-radiography, by photo-electric absorptiometer and by spectrograph, are standard. Electro-magnetic flaw-detection is applied to all steel castings for aircraft and other special applications.

You can SAFELY *specify David Brown castings*

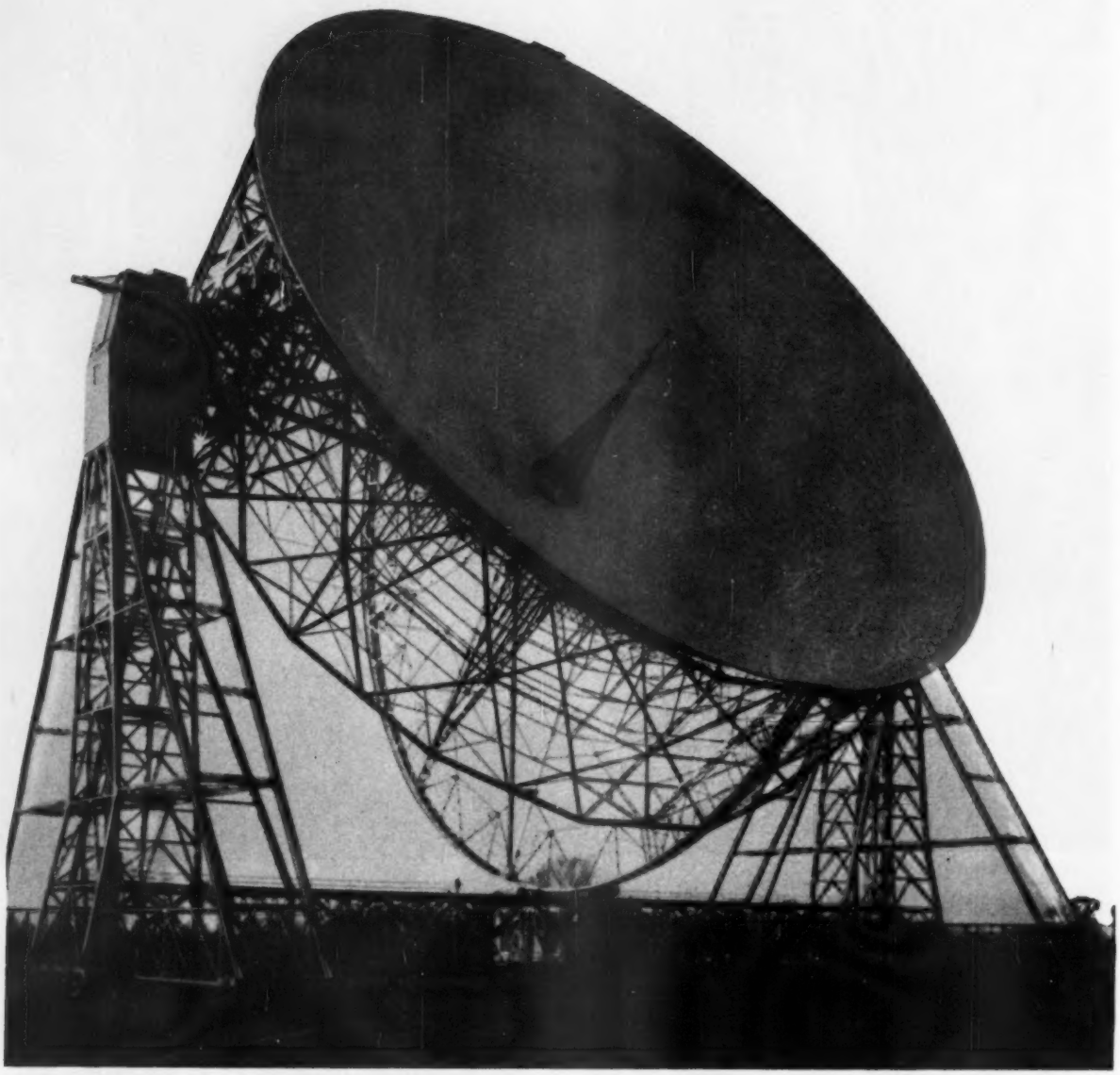
DAVID BROWN

100 YEARS 1860-1960

THE DAVID BROWN CORPORATION (SALES) LIMITED

Foundries Division, Penistone, Nr. Sheffield. Telephone: Penistone 3311

CA/5981



"I THOUGHT I HEARD SOMETHING!"

You did, and it doesn't require a detector as sensitive as this vast radio telescope to hear that many foundrymen and metallurgists rely upon us for their supply of special refined pig irons.

BRADLEY & FOSTER LIMITED

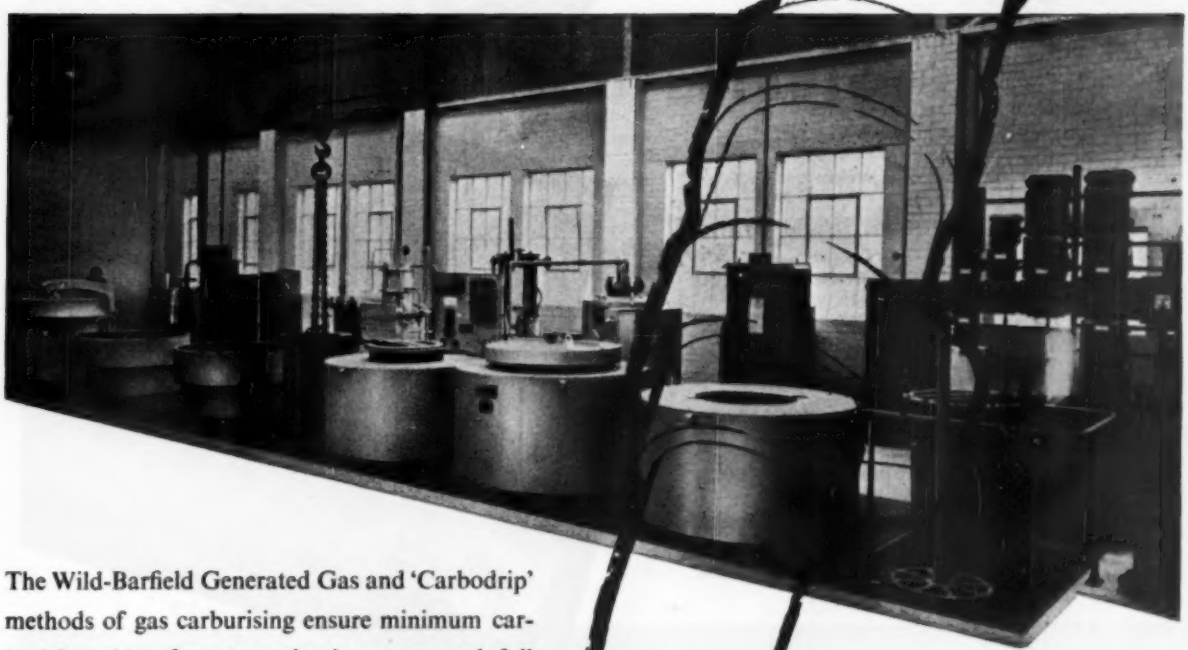
FOR QUALITY CONTROLLED REFINED PIG IRON

DARLASTON · STAFFORDSHIRE

Telephone: JAMes Bridge 2353 (7 lines) Telegrams: BRADLEY DARLASTON

A member of the Staveley Coal & Iron Co. Ltd. Group

WILD BARFIELD
GAS CARBURISING



The Wild-Barfield Generated Gas and 'Carbodrip' methods of gas carburising ensure minimum carburising time, fastest production rates and full quality control. Write to us for advice on the application of gas carburising for your work.

FOR *ALL* HEAT-TREATMENT PURPOSES

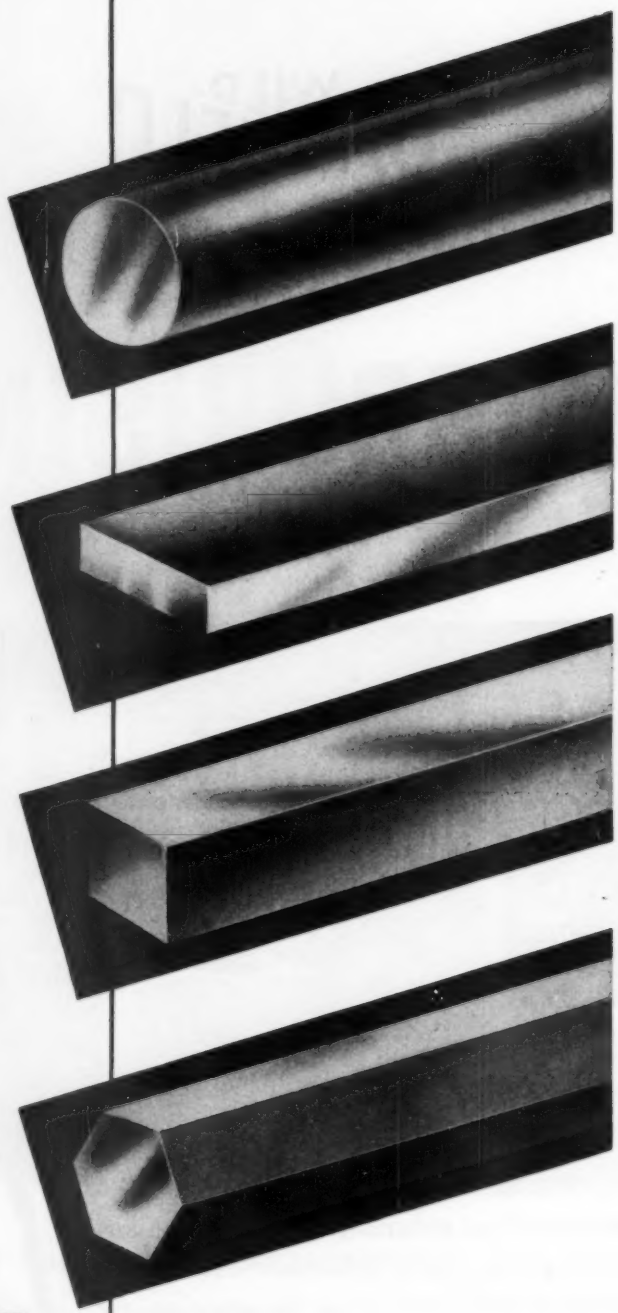
ELECTRIC WILD BARFIELD FURNACES

WILD-BARFIELD ELECTRIC FURNACES LIMITED

ELECFURN WORKS, OTTERSPOOL WAY, WATFORD BY-PASS, WATFORD, HERTS. TELEPHONE: WATFORD 26091 (8 LINES)

W.B. 90

Dependability and Quality in Dunelt Special purpose Alloy and Carbon Steels



Black rolled, bright drawn or smooth ground, in heat-treated or unheated conditions. Free cutting steels, heat-resisting steels, die steels, shear blade steels, high-speed tool steels, stainless steels, valve steels, hollow steel bars.

Dunelt

DUNFORD & ELLIOTT (SHEFFIELD) LTD
ATTERCLIFFE WHARF WORKS, SHEFFIELD 9

Telephone: 41121 (5 lines)

Telegrams: Blooms, Sheffield, 9

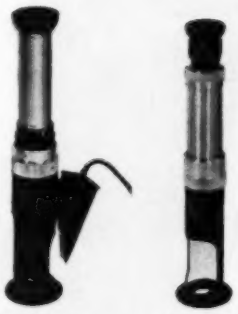
London Office: Linford Street, S.W.8

Birmingham Office: 25 Burlington Chambers, 118 New Street, 2

BRL 1.

L. 9a.
L. 9b.

M. 4

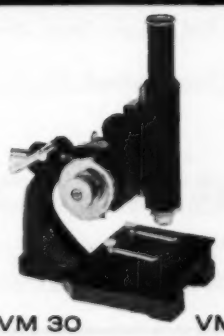


M. 4E

M. 40

BRM 40

BRM 120



VM 30

VM 60

JACKMAN

FOR

HARDNESS TESTING EQUIPMENT

MEASURING MICROSCOPES FOR BRINELL & VICKERS TESTS

BRL 1	*Pocket Microscope*	Magnification × 6	
	Field of vision	15 m/m	
	Scale Divisions	0·2 m/m	
	Built-in Battery Illumination.		
L.9a	Magnification	× 16	
	Field of vision	6 m/m	
	Scale Divisions	0·1 m/m	Can be fitted with
L.9b	Magnification	× 16	lamp illumination
	Field of vision	6 m/m	as shown.
	Scale Divisions	0·05 m/m	
M.4	Two Magnifications (by sliding tube)	× 20 in retracted position × 40 in extended position	
	Field of vision	retracted 5·0 m/m, extended 2·5 m/m	
	Scale Divisions	0·1 m/m–0·05 m/m	
		Can be fitted with lamp illumination as shown at M.4.E.	
M.40	Magnification	× 40	
	Field of vision	4 m/m	
	Scale Divisions	0·02 m/m	
	The measuring scale can be rotated to facilitate measuring in different directions.		
BRM 40	Magnification	× 40	
	Field of vision	4 m/m	
	Scale Divisions	0·02 m/m	
BRM 120	Magnification	× 120	
	Field of vision	1·0 m/m	
	Scale Divisions	0·005 m/m	
	Built in Battery illumination.		
	SLIDE MOUNTED FOR PRECISION MEASURING.		
VM 30	Magnification	× 30	
	Measuring range	0–20 m/m	
	Field of vision	3·6 m/m	
	Scale Divisions	0·001 m/m	
VM 60	Magnification	× 60	
	Measuring range	0–20 m/m	
	Field of vision	1·8 m/m	
	Scale Divisions	0·001 m/m	
	The Microscope tube, with cross hair eye-piece is mounted on a slide which is moved laterally by means of a measuring spindle to scan diameter or diagonal of impression. Readings of 0·001 m/m can be made by the vernier scale.		

J.W. JACKMAN & CO LTD

Vulcan Works, Blackfriars Road, Manchester 3.
Telephone : DEAnsgate 4648 (3 lines)
Telegrams : BLAST, Manchester.

A new handbook on machining

Details of techniques successfully used for machining the Wiggin high-nickel alloys are given in this new handbook, available on request.

These recommendations cover:

nickel
* 'MONEL' nickel-copper alloy
* 'K' MONEL age-hardenable nickel-copper alloy
* 'NIMONIC' creep-resisting alloys
* 'NIMOCAST' heat-resisting casting alloys
* 'CORRONEL' corrosion-resisting alloys
* 'NILO' controlled-expansion alloys
* 'INCONEL' nickel-chromium-iron alloy

* *Trade Mark*

HENRY WIGGIN AND COMPANY LIMITED
WIGGIN STREET BIRMINGHAM 16

To Henry Wiggin & Co. Ltd. Wiggin Street, Birmingham 16

Please send me a copy of your handbook 'Machining Wiggin High-Nickel Alloys'.

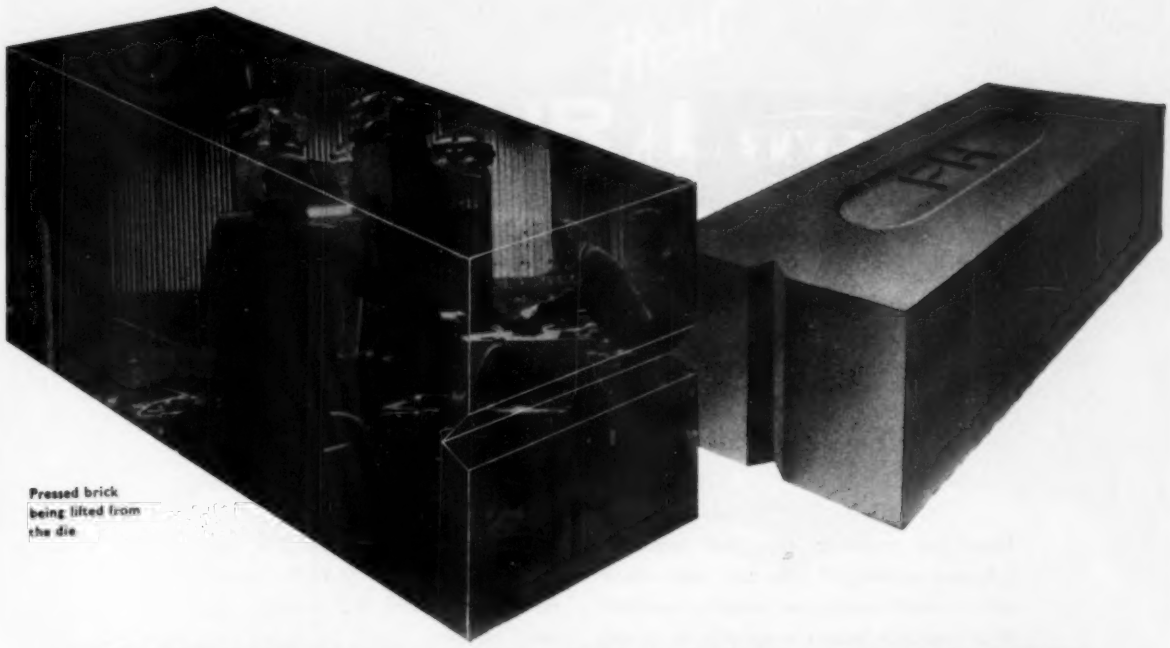
NAME_____

APPOINTMENT OR DEPARTMENT_____

COMPANY AND ADDRESS_____

_____ ME/M32/10

TGA 9121



Pressed brick being lifted from the die

PRESSING PROBLEM SOLVED

Pickford Holland install the latest hydraulic presses for standard and special shapes

Refractory bricks today must be absolutely accurate in size and shape. These qualities, combined with unerring consistency in texture and performance are achieved by Pickford Holland through the medium of the most modern plant and equipment.

In Pickford Holland works, the very latest crushing, grinding and mixing plant, powerful hydraulic presses and continuous tunnel firing kilns have been and are being installed. Rigid control of the various processes is strictly observed, and the finished bricks are carefully inspected and tested before being despatched to the consumer.

More and more Pickford Holland refractory bricks are being supplied to steel and other industries throughout the world and the demand still grows. This surely points to the success of this policy of plant modernisation and is a tribute to the lasting service that these bricks give.

PICKFORD HOLLAND *Refractory Bricks*

Consistent in Size, Shape, Texture and Performance

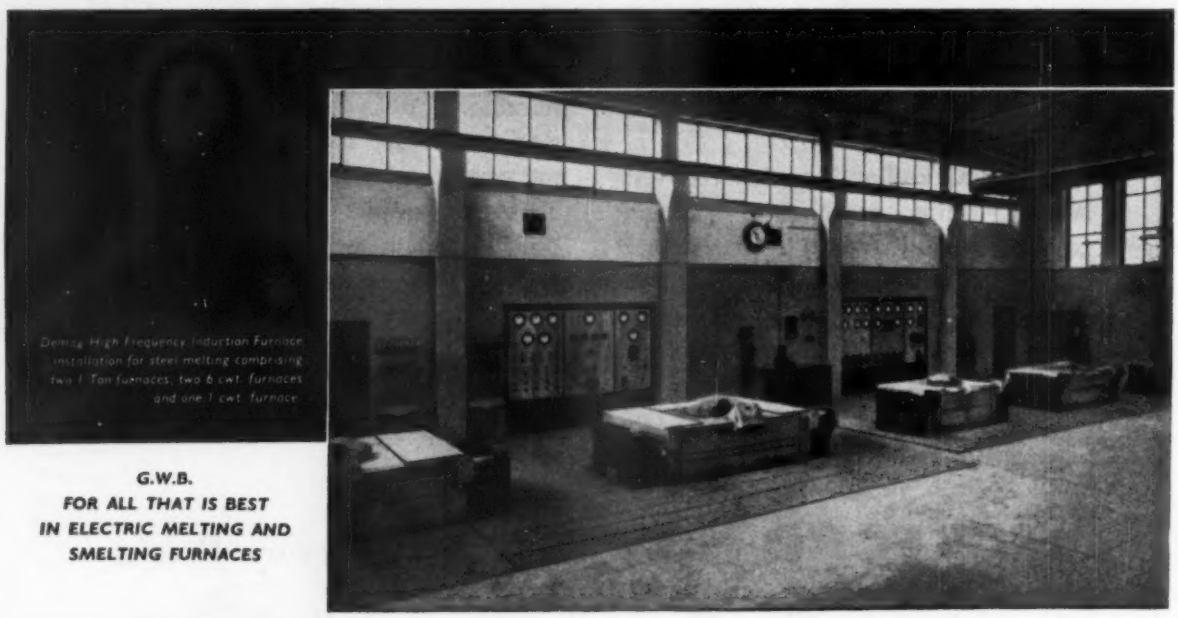
PICKFORD, HOLLAND & CO. LTD., 381 FULWOOD ROAD, SHEFFIELD 10. TELEPHONE 33921

This GWB DEMAG alliance could mean a lot to you

There are problems associated with the induction melting of irons and steels which make it imperative for the intending purchaser of an induction furnace to consider all aspects of his production so as to obtain the most suitable furnace for his needs. Even for the same metal, the same furnace will not necessarily be the best type when consideration is given to charge characteristics and melting programme. Having access to the wide range of designs and long experience of Demag, G.W.B. are now in a position to offer the most suitable furnace to suit your own particular project. G.W.B. British built furnaces available for melting irons and steels include:

- **Crucible Type Furnaces for Mains Frequency or motor alternator operation.**
- **Channel Type Mains Frequency Furnaces.**

The electric induction method of melting irons or steels can solve your melting problems, and G.W.B. can help you in the choice of the correct induction furnace.

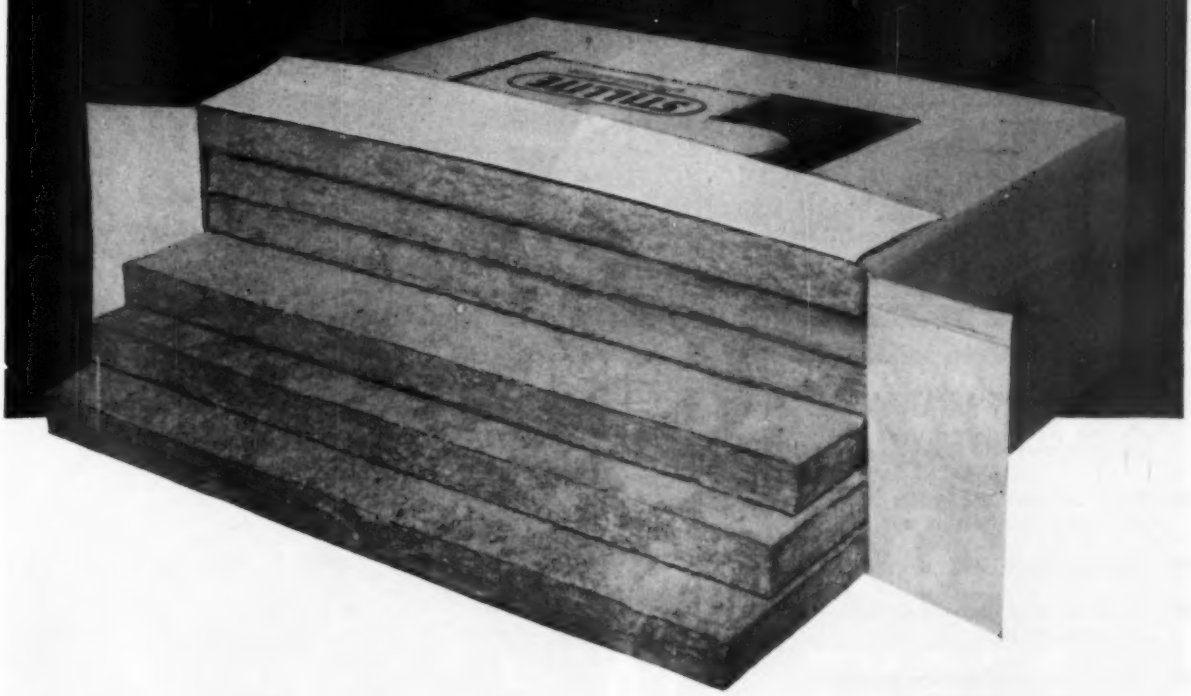


Demag High Frequency Induction Furnace installation for steel melting comprising two 1 Ton furnaces, two 6 cwt. furnaces and one 1 cwt. furnace.

G.W.B.
FOR ALL THAT IS BEST IN ELECTRIC MELTING AND SMELTING FURNACES

GWB **G.W.B. FURNACES LIMITED**
P.O. BOX 4 · DIBDALE WORKS · DUDLEY · WORCS Telephone: Dudley 55455
G.W.B. LD6
Associated with Gibbons Bros. Ltd. & Wild-Barfield Electric Furnaces Ltd.

CUT YOUR Heat LOSSES with S.R.10



The furnace industry is well acquainted with THERBLOC* for insulation up to 1,500°F. Where lower temperatures are involved, for example core stoves and paint booths, consider S.R.10 Mineral Wool slabs. An inexpensive, yet, valuable material not only for maintaining temperatures and reducing fuel bills but also to make working conditions more acceptable to operators.

* THERBLOC is a highly efficient Mineral Wool Slab which is being used extensively in place of diatomite as a backing insulant at interface temperatures up to 815°C. Write for Technical Data No: 5 — THERBLOC for furnace and stove insulation:

STILLITE

Regd. Trade Mark

STILLITE PRODUCTS LTD.
15, Whitehall, London, S.W.1.

Telephone: Whitehall 0922/7 and at St. Vincent St., Glasgow C.2. Telephone: Central 4292

To: STILLITE PRODUCTS LTD., 15, Whitehall, London, S.W.1

Please send me Technical Data No. 10

NAME _____

ADDRESS _____

Just attach this coupon to your letterhead METALLURGIA

Baldwin Atomat Nucleonic Thickness Gauges

ACCURATE, CONTINUOUS, NON-CONTACT INSPECTION

SAVES MATERIAL, LABOUR AND TIME!

The Atomat Principle

RAY SOURCE

MATERIAL

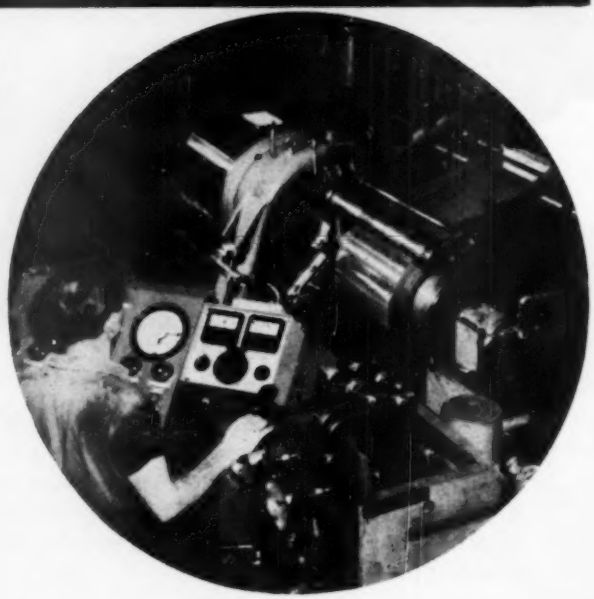
RAY DETECTOR

Amount of rays passing through material indicates thickness or weight per unit area.

That's the very basic explanation of the Atomat principle. There are three main gauges; the Atomat Cold Strip Gauge, the Hot Strip Gauge and the Beta Gauge.
In addition there are special purpose variations, made to meet the requirements of many different industries.

HERE'S WHAT AN ATOMAT GAUGE CAN OFFER YOU

- **Time and material saving both in production and setting up**
- **High accuracy**
- **Calibration in your usual units of measurement**
- **Continuous readings for materials in constant production**
- **Auto standardisation and control if you require**
- **Minimum maintenance**



Baldwin Atomats are already boosting production and cutting costs in the paper, metal rolling, rubber and plastics industries. Highly successful applications also include the measuring of selenium on aluminium, coatings of paint and lacquers, density of wood chips, coatings of grit on abrasive papers and padding and resin impregnation in the textile industry. But the potential of Baldwin Atomat Nucleonic Gauges has hardly been tapped.
Is there a place for them in your plant?

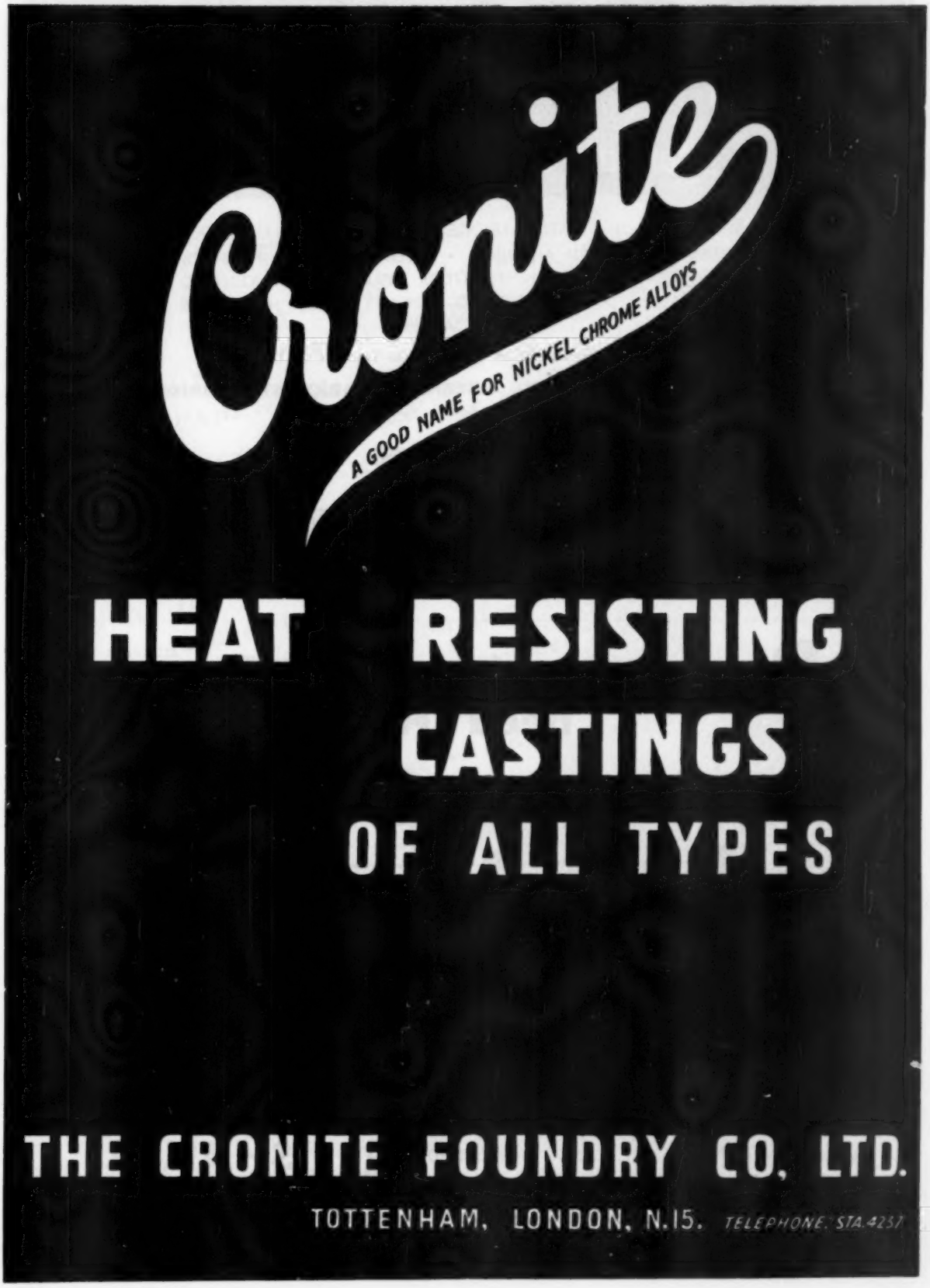
INSTRUMENT DIVISION

Send for the Baldwin Brochure MA/124. It gives full information on Atomat Gauges clearly and concisely.

BALDWIN INDUSTRIAL CONTROLS

Baldwin Instrument Company Limited, Dartford, Kent A Harper Group Company

Telephone : DARTFORD 20948 & 26411 *Cables and Telex : Baldwin, Dartford*


Cronite
A GOOD NAME FOR NICKEL CHROME ALLOYS
HEAT RESISTING
CASTINGS
OF ALL TYPES
THE CRONITE FOUNDRY CO. LTD.
TOTTENHAM, LONDON, N.15. TELEPHONE: STA.4231

refractories

for all types of furnaces

SEMI SILICA • STOURBRIDGE FIREBRICK • ALUMINOUS FIREBRICK • HIGH ALUMINA • SILLIMANITE • FIRE BRICK INSULATION • HIGH TEMPERATURE INSULATION • JOINTING MATERIALS • AIR-SETTING CEMENTS • CASTABLES MOULDABLES

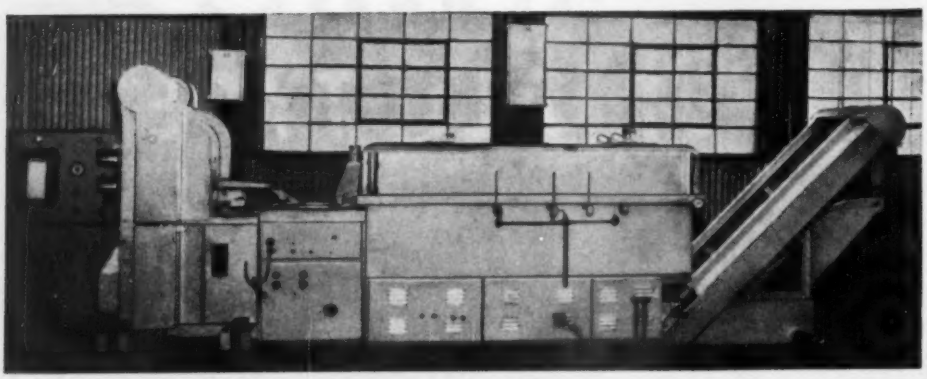
Technical details and prices of all grades available on request.

E. J. & J. PEARSON LTD. FIREBRICK WORKS, STOURBRIDGE

Telephone : Brierley Hill 77201

EJ&JP

Do your nuts and bolts need HARDENING ?



For loadings from 120 lbs/hr to 450 lbs/hr

Incorporating the most up-to-date design for automatic heat treatment of small components, e.g. nuts, bolts, springs, washers, etc,

★ LOW IN CAPITAL COST, EASILY MAINTAINED

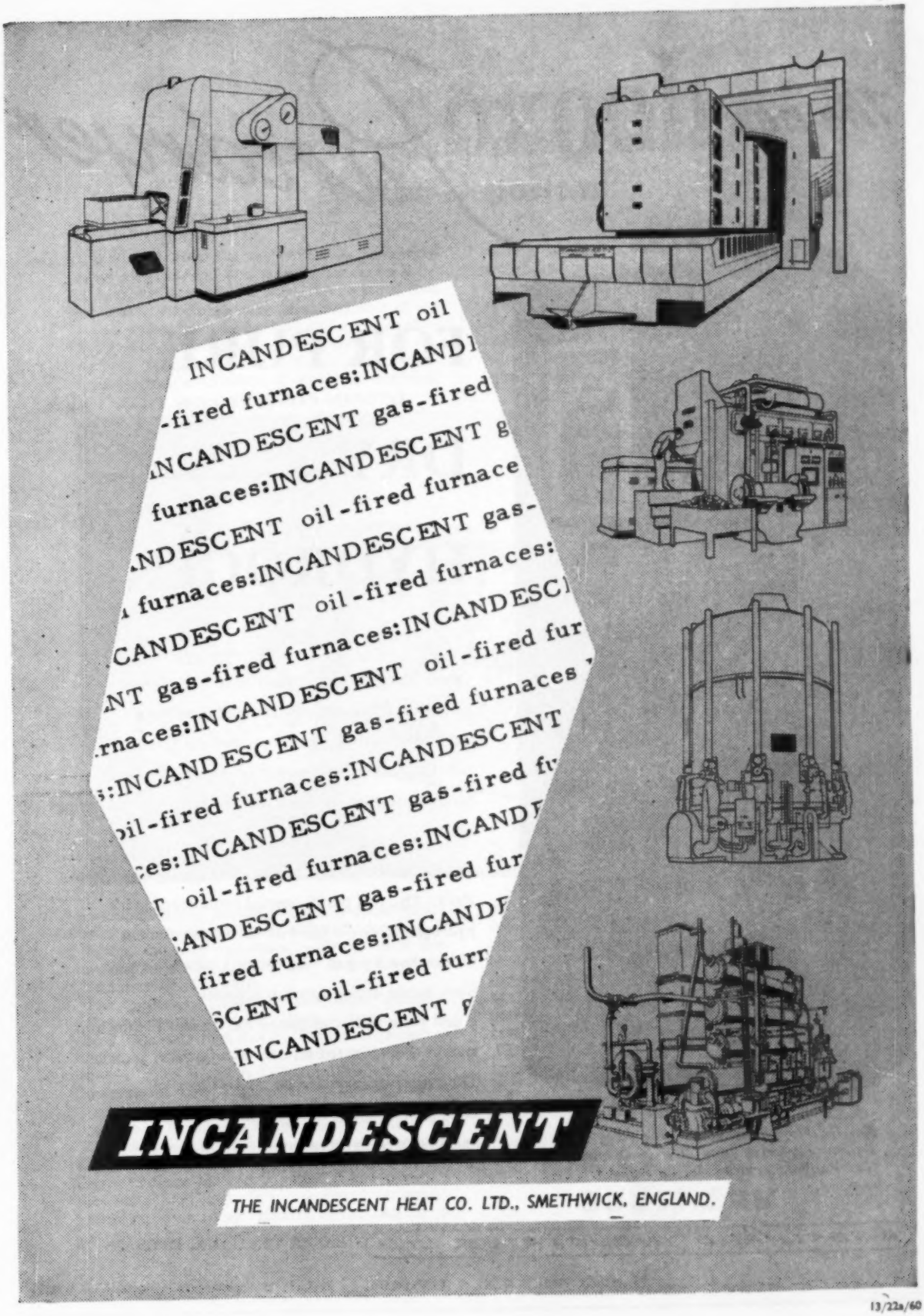
Write for new Shaker Hearth descriptive literature

4 standard size SHAKER HEARTHS

THE FURNACE CONSTRUCTION CO. LTD.

21 St. James Road, Dudley, Worcs. *Tel.: Dudley 54649 & 53751*

F.C.1


INCANDESCENT oil
-fired furnaces:INCAND
NCANDESCENT gas-fired
furnaces:INCANDESCENT g
NDESCENT oil-fired furnace
furnaces:INCANDESCENT gas-
CANDESCENT oil-fired furnaces:
NT gas-fired furnaces:INCANDESC
rnaces:INCANDESCENT oil-fired fur
;:INCANDESCENT gas-fired furnaces
oil-fired furnaces:INCANDESCENT
es:INCANDESCENT gas-fired fu
oil-fired furnaces:INCANDE
ANDESCENT gas-fired fur
fired furnaces:INCANDE
SCENT oil-fired furn
INCANDESCENT
INCANDESCENT
THE INCANDESCENT HEAT CO. LTD., SMETHWICK, ENGLAND.

The new deoxo Puridryer

FOR PURE

OXYGEN CONTENT LESS THAN 1 p.p.m.

DRY

DEW POINT MINUS 100°F

HYDROGEN

Deoxo catalytic gas purifiers have become widely accepted as the most efficient and economical method of purifying certain industrial gases. The new Deoxo Puridryer combines the features of this process together with an automatically operated drying unit.

The Deoxo Puridryer, having a maximum capacity of 100 s.c.f.h., will purify normal commercial grade hydrogen to give a gas with an oxygen content of less than 1 p.p.m. By use of Linde Molecular Sieve as the drying agent, it achieves a dew point as low as minus 100 degrees F. which enables gas to be fed directly to a furnace. The Puridryer may also be used with other gases such as nitrogen, argon, neon and saturated hydrocarbons.

● *Further information regarding the Deoxo Puridryer and Deoxo Catalytic Gas Purifiers is available on request.*

ENGELHARD INDUSTRIES, LTD. **BAKER PLATINUM DIVISION**

52 HIGH HOLBORN · LONDON · W.C.1 · *Telephone: CHAncery 8711 & 6306*

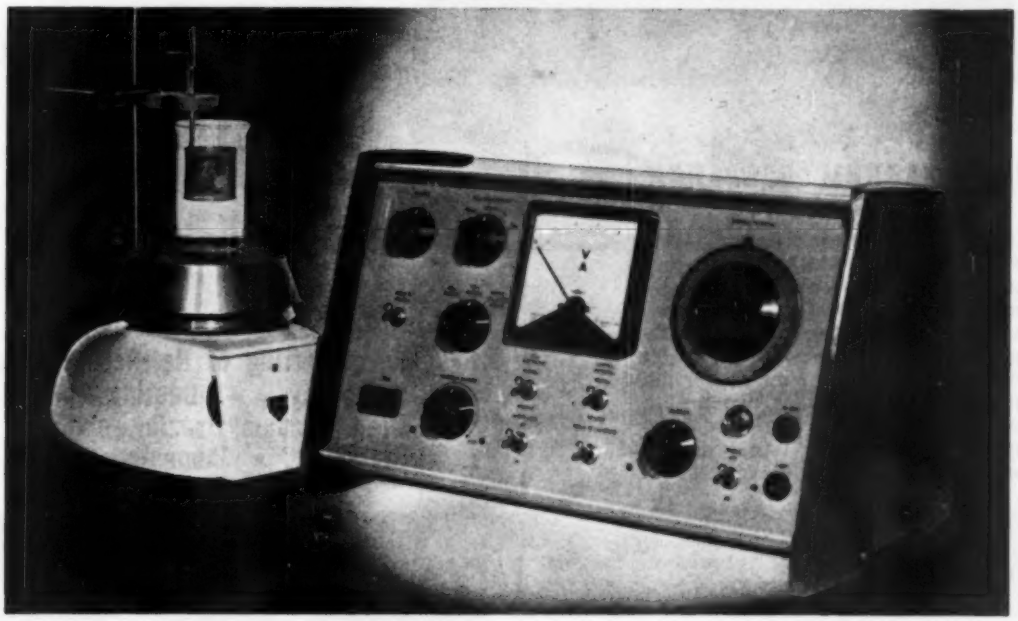
A 1654

Wadsworth Controlled Potential Electro-Depositor

ELECTRO-DEPOSITION has long been recognised as an analytical and separative technique for solutions containing metallic ions. The method may be applied where the ionic concentrations of the metals present in solution vary widely, separation being best achieved where the potential of the working electrode relative to the solution is controlled, using a reference electrode as described independently by Sand & Fischer. Manual control of the electrode potential, although possible, is tedious and time consuming, with the result that automatic control circuits have been developed by a number of workers.

The Southern Analytical controlled potential electro-depositor is based upon a design due to N. J. Wadsworth of R.A.E., Farnborough, and is intended primarily for use with platinum electrodes. The circuit is fully transistorised in the interests of compactness and reliability and is capable of supplying a maximum controlled current of 10 amperes to the electrolysis cell. In operation, the required cathode potential is preset upon a built-in high grade potentiometer. Any error between the preset potential and that of a reference half-cell (e.g. saturated calomel), mounted immediately adjacent to the cathode, is applied to an amplifier which controls the current passing through the cell in such a sense that the potential error tends towards zero.

In order to ensure that thermal drift in the control amplifier is held at a very low level, a water-cooled heat sink is employed to maintain the transistors at a substantially constant temperature. The accuracy of control attained may be judged from the fact that the incremental error in electrode potential as a function of cell current has a mean value of 1.6 millivolts/ampere; thus, when the electrolysis current has fallen to the low levels obtaining towards the end of a deposition, extremely close control is established. It is noteworthy that the potential defined by the built-in potentiometer cannot be exceeded as cell current cuts off at zero potential error.



The apparatus is supplied complete with leads for connection to the user's own electrode assembly. If desired however, suitable standard accessory equipment can be provided.

SOUTHERN *Analytical*

SOUTHERN ANALYTICAL LIMITED CAMBERLEY SURREY TELEPHONE: CAMBERLEY 3401

The new deoxo Puridryer

FOR PURE

OXYGEN CONTENT LESS THAN 1 p.p.m.

DRY **DEW POINT MINUS 100°F**

HYDROGEN

Deoxo catalytic gas purifiers have become widely accepted as the most efficient and economical method of purifying certain industrial gases. The new Deoxo Puridryer combines the features of this process together with an automatically operated drying unit.

The Deoxo Puridryer, having a maximum capacity of 100 s.c.f.h., will purify normal commercial grade hydrogen to give a gas with an oxygen content of less than 1 p.p.m. By use of Linde Molecular Sieve as the drying agent, it achieves a dew point as low as minus 100 degrees F. which enables gas to be fed directly to a furnace. The Puridryer may also be used with other gases such as nitrogen, argon, neon and saturated hydrocarbons.

● *Further information regarding the Deoxo Puridryer and Deoxo Catalytic Gas Purifiers is available on request.*

ENGELHARD INDUSTRIES, LTD. **BAKER PLATINUM DIVISION**

52 HIGH HOLBORN · LONDON · W.C.1 · *Telephone: CHAncery 8711 & 6906*

A 1654

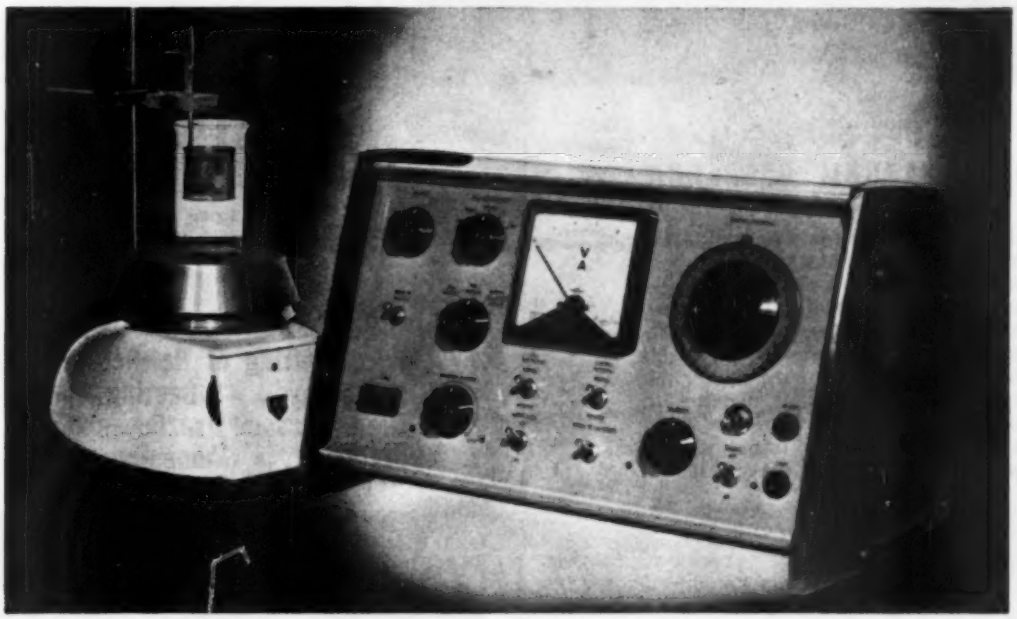
Wadsworth Controlled Potential Electro-Depositor

ELECTRO-DEPOSITION has long been recognised as an analytical and separative technique for solutions containing metallic ions. The method may be applied where the ionic concentrations of the metals present in solution vary widely, separation being best achieved where the potential of the working electrode relative to the solution is controlled, using a reference electrode as described independently by Sand & Fischer. Manual control of the electrode potential, although possible, is tedious and time consuming, with the result that automatic control circuits have been developed by a number of workers.

The Southern Analytical controlled potential electro-depositor is based upon a design due to N. J. Wadsworth of R.A.E., Farnborough, and is intended primarily for use with platinum electrodes. The circuit is fully transistorised in the interests of compactness and reliability and is capable of supplying a maximum controlled current of 10 amperes to the electrolysis cell. In operation, the required cathode potential is preset upon a built-in high grade potentiometer. Any error between the preset potential and that of a reference half-cell (e.g. saturated calomel), mounted immediately adjacent to the cathode, is applied to an amplifier which controls the current passing through the cell in such a sense that the potential error tends towards zero.

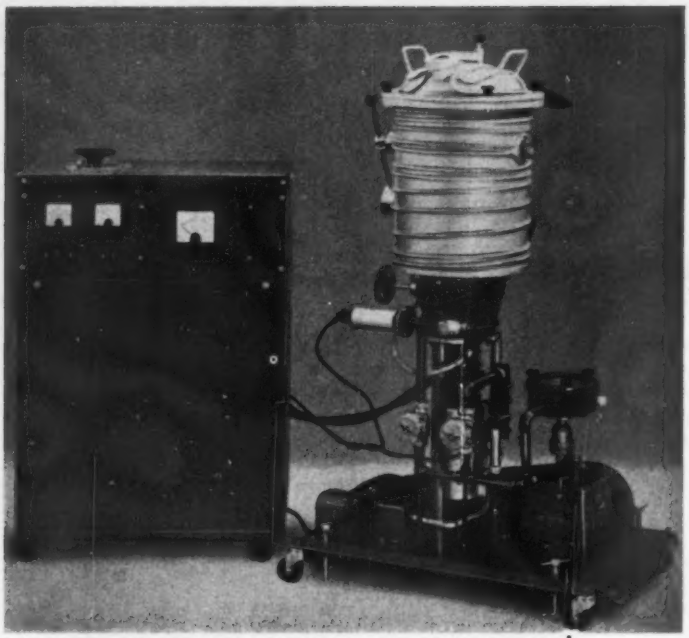
In order to ensure that thermal drift in the control amplifier is held at a very low level, a water-cooled heat sink is employed to maintain the transistors at a substantially constant temperature. The accuracy of control attained may be judged from the fact that the incremental error in electrode potential as a function of cell current has a mean value of 1.6 millivolts/ampere; thus, when the electrolysis current has fallen to the low levels obtaining towards the end of a deposition, extremely close control is established. It is noteworthy that the potential defined by the built-in potentiometer cannot be exceeded as cell current cuts off at zero potential error.

The apparatus is supplied complete with leads for connection to the user's own electrode assembly. If desired however, suitable standard accessory equipment can be provided.



SOUTHERN *Analytical*

SOUTHERN ANALYTICAL LIMITED CAMBERLEY SURREY TELEPHONE: CAMBERLEY 3401



It's the brightest spark in the metallurgist's laboratory

When investigating

Pure Melting of Refractory Metals and Alloys ▪ Casting ▪ High Vacuum Brazing and Sintering ▪ Annealing, etc.

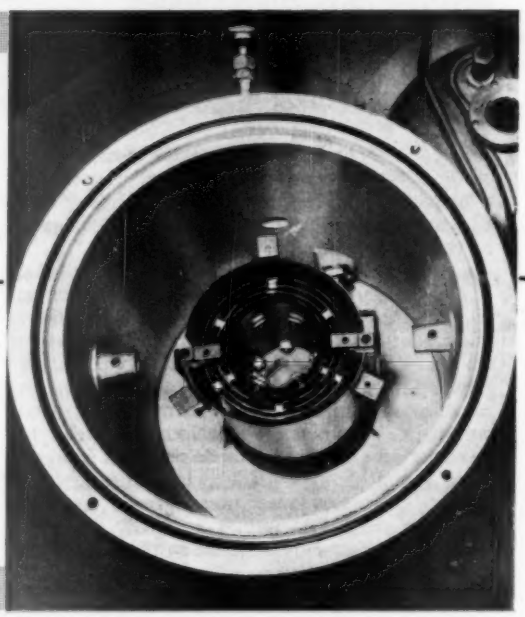
'SPEEDIVAC'

HIGH VACUUM RESEARCH FURNACE

Although designed primarily for research into metallurgical problems, this small furnace is already being used for production of pure metals for transistors and the brazing of industrial diamonds. With its powerful high vacuum pumping system it is an actual production furnace in miniature having a melting capacity of ½ lb. (steel) and a temperature range of up to 1,800° C.

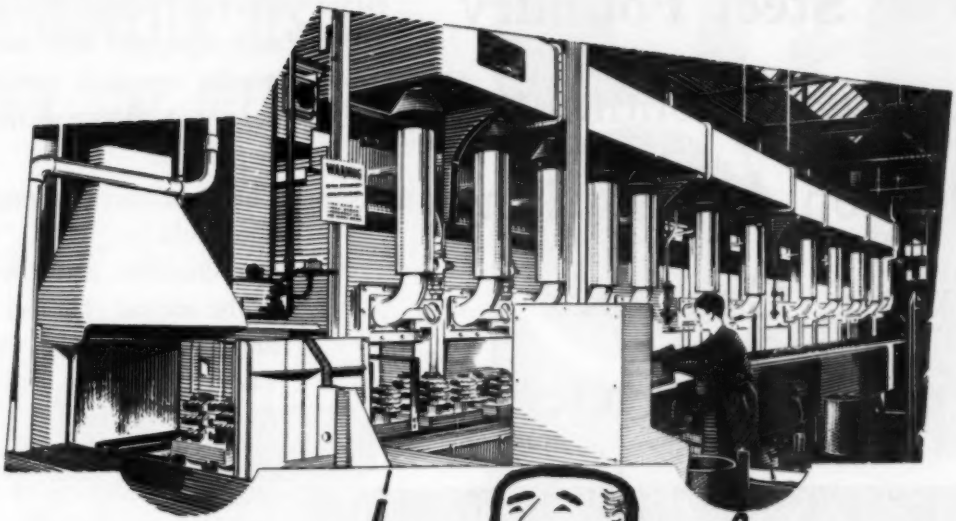
STATIONARY RADIANT HEATER ASSEMBLY

In place of the stainless steel pot normally fitted for melting purposes, a standard radiant heater assembly (as illustrated) can be fitted for general heat treatment up to temperatures of 1,500° C. (1,700° C. with increased power supply). An evenly heated working space is provided (2 inches dia. by 4 inches high) for investigating problems concerned with the brazing of multiple joints, vacuum sintering and other heat treatment processes. Heating is by a molybdenum wire heater and suitable control and observation windows are fitted to allow full supervision of the process.

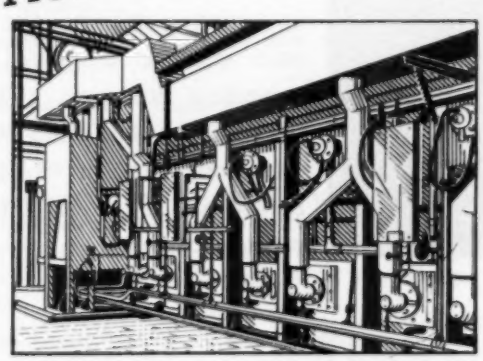


EDWARDS HIGH VACUUM LTD · MANOR ROYAL · CRAWLEY · SUSSEX · ENGLAND · Crawley 1500

PROPAGAS PROPANE



carries weight in the Motor Industry



These illustrations, by courtesy of Ford Motor Co. Ltd, show two of many continuous gas carburizing furnaces installed at their Dagenham factory, using endothermic atmospheres produced from PROPAGAS.

PROPAGAS provides industry not only with a high calorific value fuel gas (approximately 2,500 b.t.u. cubic foot) but also with an excellent medium for the production of special furnace atmospheres. It is widely used for gas carburizing, carbonitriding and bright annealing of ferrous and non-ferrous metals.

BOTTOGAS Butane, like Propagas, is a petroleum gas delivered and stored as a liquid under moderate pressure. Bottogas is used as a fuel for fork lift trucks and for many other specialised applications.

PROPAGAS Propane and **BOTTOGAS Butane** come from the great British refineries of the Shell, Eagle and BP Groups, backed by a technical service second to none and with a complete sales organisation covering the United Kingdom.

See us at STAND No. 424, Grand Hall Gallery, Olympia, Public Works Exhibition

SHELL

SHELL-MEX AND B.P. GASES LIMITED

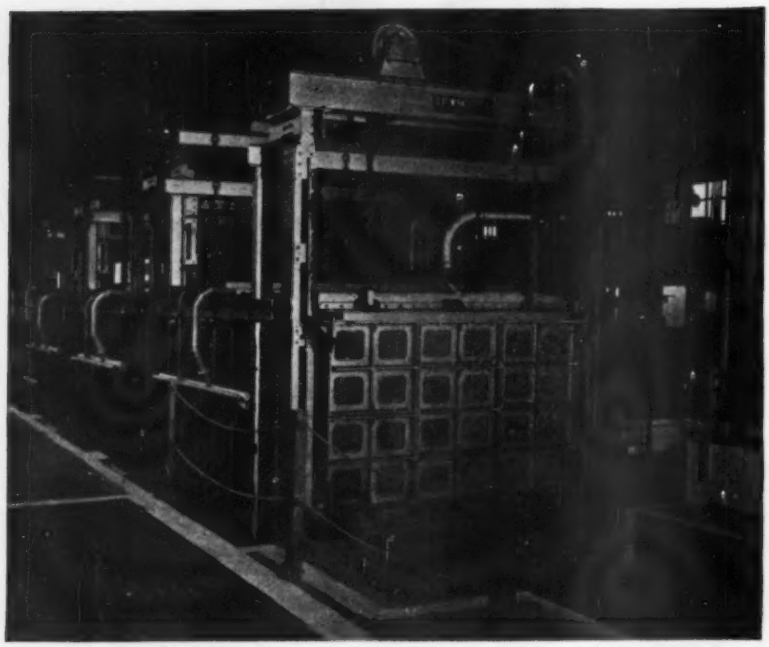
(Regd. users of trade marks)

"The biggest distributors of Propane in the U.K."

CECIL CHAMBERS 76-86 STRAND LONDON WC2 Telephone: TEMple Bar 1234

BP

Cut fuel and labour costs in your **Steel Foundry** and achieve continuity of production by installing a **Triple Chamber Quenching Furnace**



By permission of Messrs. Edgar Allan & Co.Ltd.

The three separate chambers of this City Gas Fired Furnace are 12 ft. long by 10 ft. in effective width. They are each equipped with two electrically operated self-locking doors and operate as independent units.

The castings are preheated from cold to 300° C. in the first chamber and then pass to the second chamber where they are raised to 750° C. They are finally heated to 1,100° C. in the third chamber, and after soaking are quickly withdrawn by an extractor gear and conveyed to the oil or water tanks for quenching. The chambers are equipped with instruments for the automatic control of temperature, air/gas ratio and pressure. Prescribed heating curves can easily be maintained.

By utilising the third chamber as a cooling chamber the furnace can be employed for annealing purposes. When desired, the first and third chambers can be independently used for the batch treatment of castings.

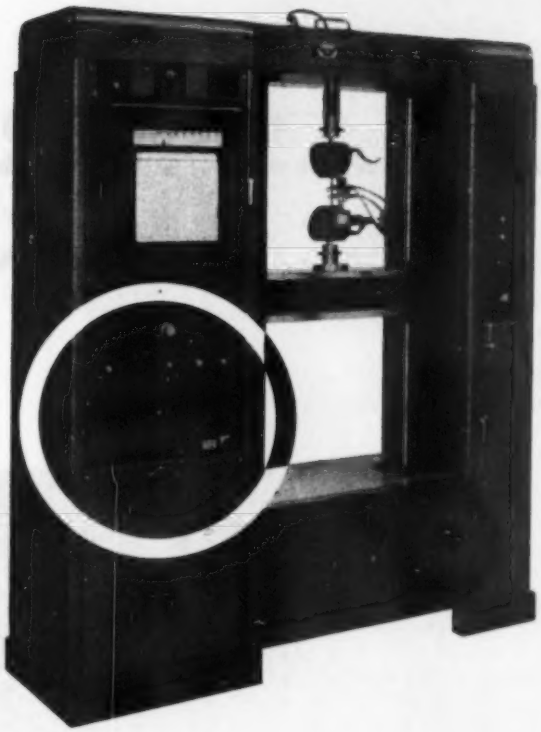
WINCOTT FURNACES

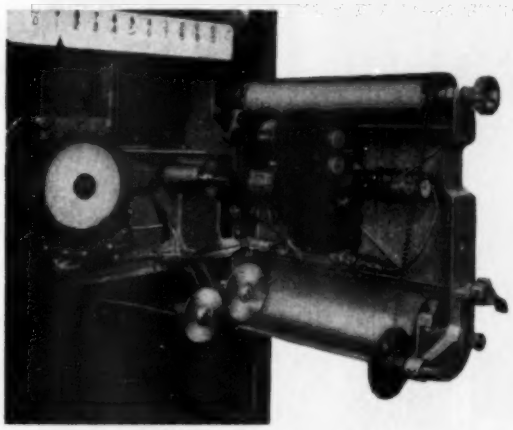
G.P. WINCOTT LIMITED SHEFFIELD, ENGLAND

Telegrams: WINCOTT, SHEFFIELD. Telephone: 20211/2

EXTENSOMETER TESTING WHEN YOU NEED IT:

the Instron XY recorder makes it as simple as flipping a switch!





When you want to use extensometers for certain testing applications . . .

. . . you don't have to buy a new tester (if you already have an Instron).

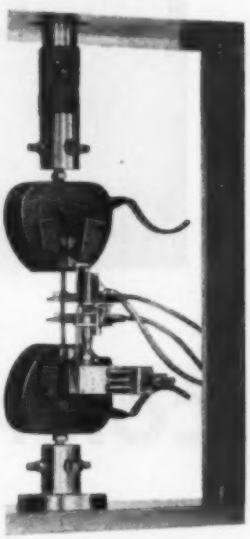
. . . you don't have to subject your Instron to costly modification.

All you have to do is add this field-proven, high-precision accessory—the XY Chart Drive System—and you have a superbly efficient servo system which lets you change over, instantly, from sample elongation by grip separation—to extensometer measurement, at the flip of a switch!

Here's one more example of what we mean when we say you can do more with an Instron. And—you get this incomparable flexibility in testing only if and when you need it. This is an optional accessory—not a standard item built into the Instron to add to your expense whether you need it or not.

The XY Chart Drive Accessory—what it is :
a high performance servo system for driving the chart of the Instron recorder. Operable from most types of extensometers, including differential transformers, small synchros, resistance potentiometers and strain gauges.

Varying degrees of magnification, depending on extensometer type and gear ratio for everything from metals to miracle plastics.



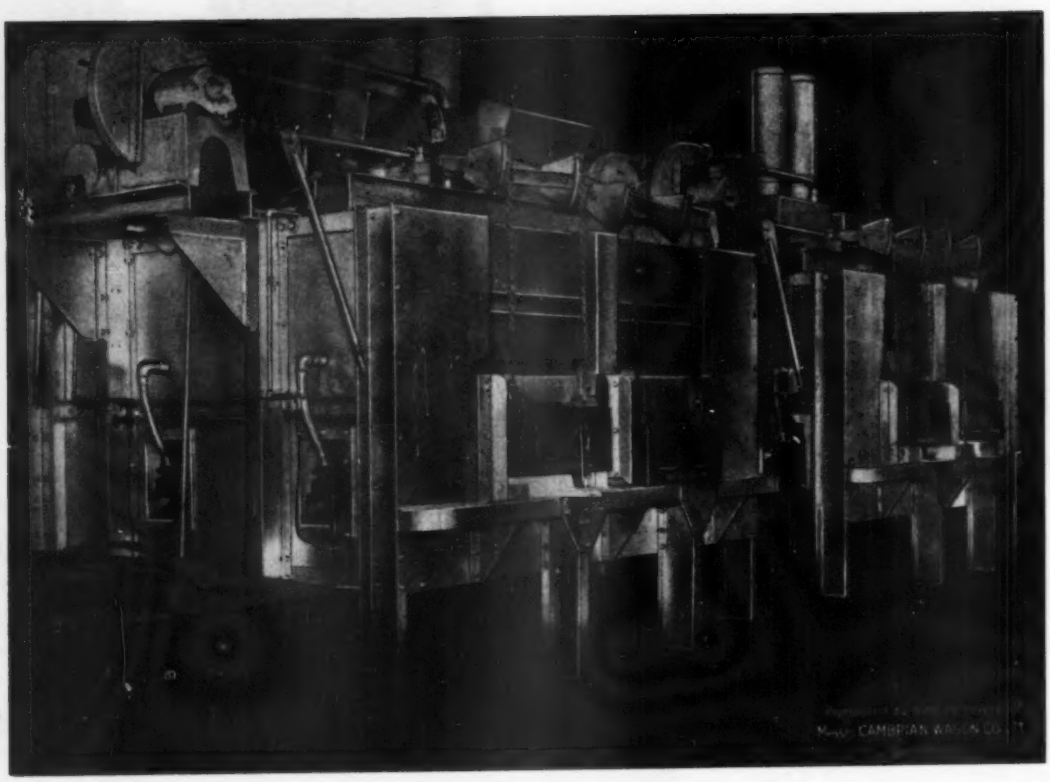
Unlimited chart travel to enable switching from extensometer to time drive for relaxation measurement.

This accessory performs equally well with all Instrons, no matter what their vintage. Installation is no problem.

For complete information on high precision tensile testing (whether or not it involves extensometers) write us today.

INSTRON LIMITED **P.O. Box 34, High Wycombe**

LUCAS FURNACES LTD
BIRMINGHAM



COMPLETE INSTALLATIONS AND FURNACE CONVERSIONS

Steelworks plant?

Newton Chambers are fully equipped and have many years' experience in the design, manufacture and installation of a wide range of steel works plant and ancillary equipment. May we discuss your requirements, particularly for the following?

Steelworks Plant

Steel Casting Ladles and Carriages up to 300 Tons Capacity
Hot Metal Ladles and Carriages
Torpedo Type Hot Metal Ladles and Cars
Slag Ladles and Carriages
Ingot Casting Cars
Ingot Transfer Cars
Slab Transfer Bogies
Coil Carrying Bogies
Scrap Bogies
Charging Boxes and Bogies
Roll Transfer Bogies
Special Transport Equipment
Gas Cleaning Plant (Electrostatic or Venturi Type)
Recuperators

Steel Casting Ladle and Ingot Casting Cars made for the Steel Company of Wales.

Blast Furnace Plant

Blast Furnace Plant
Hot Blast Stoves
Slag Ladles and Carriages
Pig Casting Machines
Gas Cleaning Plant
Gasholders

Newton Chambers

Remember the *scope* of NEWTON CHAMBERS

ENGINEERING DIVISION · THORNCLIFFE · SHEFFIELD

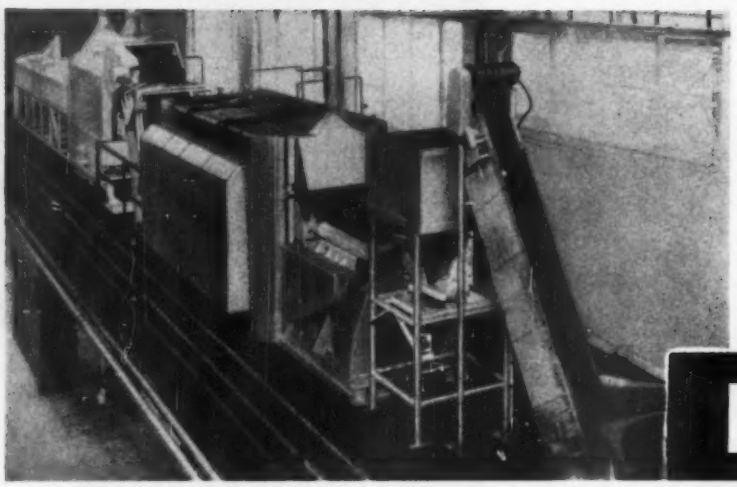
On the right lines...

BRITISH RAILWAYS

EXPRESS FREIGHT

TRAVELS FASTER ON...

TIMKEN
tapered roller bearings



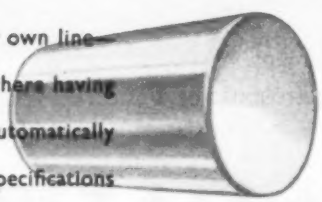
who

use

EFCO

HEAT TREATMENT PLANT

At British Timken, rollers have their own line—an EFCO continuous production line—where having been previously carburised they are automatically hardened and tempered to the precise specifications necessary for them to perform their arduous duties for British Railways.



Like Timken—be on the right lines—with EFCO

EFCO FURNACES
the best of the world's furnace designs

ELECTRIC RESISTANCE FURNACE CO. LTD
NETHERBY, QUEENS ROAD, WEYBRIDGE, SURREY · Weybridge 3891
Associated with Electro-Chemical Engineering Co. Ltd

METALLURGIA

THE BRITISH JOURNAL OF METALS
INCORPORATING THE METALLURGICAL ENGINEER

CONTENTS FOR OCTOBER, 1960 Vol. 62 No. 372.

PUBLISHED MONTHLY BY

The Kennedy Press, Ltd., 31, King Street West, Manchester, 3.
Telephone : BLAckfriars 2084.

London Office :

158, Temple Chambers, Temple Avenue, E.C.4.
FLEet Street 8914.

CONTRIBUTIONS

Readers are invited to submit articles for publication in the editorial pages : photographs and/or drawings suitable for reproduction are especially welcome. Contributions are paid for at the usual rates. We accept no responsibility in connection with submitted manuscript. All editorial communications should be addressed to The Editor, "Metallurgia," 31, King Street West, Manchester, 3.

SUBSCRIPTIONS

Subscription Rates throughout the World—30/- per annum, Post free.

ADVERTISING

Communications and enquiries should be addressed to the Advertisement Manager at Manchester.

	Page
The Small Exporter	131-132
Meeting Diary	132
The Influence of Trace Elements on Embrittlement Phenomena in Low Alloy Steels. By J. M. Capus and G. Mayer.	133-138
Low Pressure Metallurgy. Vacuum as an Inert Atmosphere. By A. S. Darling.	139-142
New Electron Beam Melting Plant	142
Better Gauge in Metal Strip Production. Further Step in Automatic Control	143
Explosive Forming of Metal	144-145
The Fabrication of Boron by Powder Metallurgical Techniques. By P. Best and S. R. Twigg	146-152
Personal News	152
The Protection of Iron and Steel by Aluminium Coatings. By D. R. Andrews.	153-158
News in Brief	158
United Steel's New Headquarters	159-160
Cold Forging Plant on Show at Hanover Machine Tool Exhibition.	161-164
News and Announcements	165-168
Recent Developments	169-172
Current Literature	173-174

LABORATORY METHODS SUPPLEMENT

The Determination of Small Amounts of Cobalt in Highly Alloyed Metals. By R. C. Rooney	175-180
A "Tailor-Made" Vacuum Furnace Installation	180

The latest development in Open Hearth Steel-making Practice

WELLMAN

Britain's foremost builders of Steel-making Plant

now offer the

AJAX Oxygen Steel-making Operation

This new steel producing technique has been incorporated in the furnace illustrated. It was invented and developed by Appleby-Frodingham Steel Company, and has already produced over ¼ million tons of ingots. A second unit has now been commissioned.

Outputs have been greatly increased with an average of five thousand tons of steel per week.

This Furnace has now 90% availability together with lower than normal refractory costs.

As licensees we invite you to consult us for either converting existing plant or providing new furnaces incorporating the Ajax Oxygen Steel-making Operation.

THE WELLMAN SMITH OWEN ENGINEERING CORPORATION LTD.

PARNELL HOUSE, WILTON ROAD, LONDON, S.W.1 WORKS: DARLASTON, South Staffs, & BELFAST.

METALLURGIA

THE BRITISH JOURNAL OF METALS

INCORPORATING THE "METALLURGICAL ENGINEER"

OCTOBER, 1960 Vol. LXII. No. 372

The Small Exporter

THE Government has called on industry to increase this country's share in the world's markets, and it is generally acknowledged that this is a necessity if our prosperity as a nation is to be maintained. We are not blessed with abundant raw material resources and the majority of our industries are dependent on imports to provide them—directly or indirectly—with the materials with which to work. A country which cannot grow sufficient food to feed its population must export in order to pay for the deficiency, and when, as in the case of the United Kingdom, there is little, if any, surplus indigenous mineral wealth, the principal export must be labour, skill, and "know-how" in the shape of manufactured goods. With these must be bought food and some of the materials into which such labour, skill and "know-how" can be built to enhance its value. It follows, therefore, that the higher the labour content of an export—including skill and "know-how" in the term—the better: in other words, it is better to export finished rather than semi-finished products, although half a loaf is better than no bread.

On the whole the importance of the export trade is widely acknowledged by all sides of industry, although the outsider may be forgiven at times for wondering whether any serious thought is given to it by either labour or management. This is particularly true in the case of "wild-cat" strikes, but even the considered pronouncements of union officials sometimes seem to suggest that industry is an Eldorado where it is only necessary to dig up a few paving stones to meet the wage demands made on it—regardless of the rough ride for all concerned which is likely to ensue. Nor is management entirely free from the charge of paying no more than lip-service to the export cause. While most managements appreciate the importance of exports, they regard the matter as the concern of the other fellow—or company—whose products are much more suitable for the export market. This is the easy way out, and whilst the attitude is not confined to the smaller firms, there are, nevertheless, large numbers of them who cannot be bothered to investigate the possibilities. In many instances this arises from a genuine conviction that the resources of a small company are insufficient to enter the export field. To such firms is addressed "Exporting is Profitable," a booklet issued recently by the National Union of Manufacturers, which opens with a statement that it has been compiled "with the object of drawing attention of small and medium-sized manufacturers to the great prizes that can be won, or have been won, by the smaller firms who have sought, and taken, advice on their export problems. It was to provide just such advice that the National Union of Manufacturers set up its Export Assistance Department immediately after World War II.

That exporting is not without its difficulties is frankly admitted and the booklet lists as the three main disadvantages; competition from local production, delay in payment, and selling at a distance. Goods sold abroad have to bear the extra cost of freight, insurance and, in some instances, an import duty, and it is likely that the firm will have to be content with a reduced profit as compared with home sales. On the other hand, export orders are usually larger than home orders and are often placed when home sales are on the decline: they thus both increase and stabilise demand, which in turn ensures a more uniform level of production and lower production costs.

Unless export orders are shipped against "Confirmed Irrevocable Letters of Credit in London"—under conditions not usually acceptable to overseas buyers these days—some time will elapse before the exporter has the money in the bank: up to four months is common for consumer goods and up to five years for capital goods. Such difficulties can be overcome by employing the services of merchant finance houses or general export merchants to ensure prompt payment in sterling, and so avoid having working capital tied up. Firms wishing to finance their own export trade can have long-dated bills discounted with the banks if they are covered by a Government Export Credits Guarantee Policy.

Many stories of the difficulties of selling at a distance are exaggerated, often emanating from firms trying to unload abroad goods they cannot sell at home. Even goods enjoying wide demand at home may be unsuitable for export, because of differing requirements overseas, but a product with good home sales is at least a potential export and should do well if the firm, after getting all the expert advice available and devising a well-thought-out sales plan, decides it is a good bet in overseas markets and prosecutes its export campaign with vigour. Any plan of this nature must provide, where necessary, for efficient after-sales service and the stocking of spare parts in the importing country: there is nothing so frustrating and so creative of ill-will than delays in obtaining spares. To sum up: selling at a distance need not be a real disadvantage if firms have good products and are willing to seek and take advice.

Turning to the advantages of exporting, the booklet reiterates the value of exports in ensuring a more even flow of work through the factory, with resultant lower production costs and the spreading of the overheads over a larger turnover. It further stresses that every export market is another basket for the production eggs, and that any export door which has been opened can be opened wider should business recede in the home or other markets. As an example of this, many firms would have been in serious trouble in 1957–58 if the U.S. and Middle East markets had not been so buoyant.

A less obvious benefit of trading in foreign markets

is that it adds to a firm's knowledge and experience, which may lead to improvements in the design of a product, to new uses for it, and even to better production methods. There is also the possibility of licensing British products on a royalty basis, or widening the firm's products by making foreign patented goods.

The rest of the booklet is devoted to an account of the way in which the Export Assistance Department works, and an outline of the range of problems already successfully tackled. More than a third of Britain's industrial output comes from firms employing less than two hundred workers. Many of these firms are turning out first-class products. Some have built up a good export trade and are, in consequence, expanding rapidly, but others have not seriously considered entering the export markets or sought expert advice. It is to them that the Export Assistance Department can be of service.

The Government cannot subsidise exports, says the National Union, but it can, and very likely will, find means of making it very difficult for firms who do not export at all. Exporting is, therefore, not only necessary but prudent; and it can also be very profitable. Hence the choice of the present time for the production of this booklet, which is issued in the hope that it will encourage established exporters to seek further markets, and others to make a serious attack on overseas markets whilst the going is good.

Meeting Diary

18th October

Institute of Metal Finishing, South-West Branch. "Methods of Preparation for Plating: (a) Abrasive Blasting," by R. A. WILDING. Assize Courts Hotel, Bristol. 7.30 p.m.

Sheffield Metallurgical Association. "Some Observations on the Austenitic Steels Used for Corrosive Duties in Chemical Plant," by E. J. HEELEY. BISRA Laboratories, Hoyle Street, Sheffield, 3. 7 p.m.

19th October

Institution of Plant Engineers, Kent Branch. "Refractory Brickwork for Boilers and Furnaces," by N. W. HINCHCLIFFE King's Head Hotel, High Street, Rochester. 7 p.m.

20th October

Institution of Mining and Metallurgy. "Mining of Cupreous Stockwork Ores at Rio Tinto, Spain," by R. N. PRYOR; and "Extraction of Copper and Silver by the Segregation Process in Peru," by F. POLLANDT. These papers will not be read, but will be submitted for discussion. They are published in Bulletin 646, Sept. 1960. Geological Society, Burlington House, Piccadilly, London, W.1. 5 p.m. Tea served from 4.30 p.m. Visitors welcome.

21st October

West of Scotland Iron and Steel Institute. "The Physical Metallurgy of Steel," by PROF. R. W. K. HONEYCOMBE. 39, Elmbank Crescent, Glasgow. 6.45 p.m.

24th October

Institute of Welding, Manchester and District Branch. "Mastering Imperfections by a Code of Good Welding Practice," by C. SPENCER. Bolton Municipal Technical College, Bolton. 7.15 p.m.

25th October

Institute of Metal Finishing, South-West Branch. "Metal Finishing in the Instrument Industry," by F. C. CARPENTER. Saracens Head Hotel, Gloucester. 7.30 p.m.

Institution of Plant Engineers, South Wales Branch. "The Thermal Insulation of Factory Buildings," by N. FOSTER. South Wales Engineers' Institute, Park Place, Cardiff. 7.30 p.m.

Sheffield Metallurgical Association. "Dolomite," by DR. D. F. MCVITTIE. BISRA Laboratories, Hoyle Street, Sheffield, 3. 7.30 p.m.

26th October

Manchester Metallurgical Society. "Metallurgical Aspects in the Development of Fast Fission Reactors," by PROF. C. R. TOTTLE. Headquarters of the Manchester Literary and Philosophical Society, George Street, Manchester. 6.30 p.m.

28th October

Institute of Metal Finishing, Sheffield and North East Branch. "The Electrodeposition Properties and Applications of the Precious Metals," by R. R. BENHAM. Grand Hotel, Sheffield. 7 p.m.

Manchester Association of Engineers. "Strain Gauges," by A. J. P. SARBERWAL. Engineers' Club, Albert Square, Manchester. 6.45 p.m.

1st November

Sheffield Metallurgical Association. "The Direct Reduction of Iron Ore and its Future in Steelmaking," by J. MACKENZIE. BISRA Laboratories, Hoyle Street, Sheffield, 3. 7 p.m.

2nd November

Institute of Welding, Manchester and District Branch. "A Survey of Fusion Welding Development," by A. A. SMITH. Reynolds Hall, Manchester College of Science and Technology. 7.15 p.m.

7th November

Institute of British Foundrymen. Sheffield Branch. "Precision in Casting," by A. SHORT. Technical College, Pond Street, Sheffield. 7 p.m.

9th November

Manchester Metallurgical Society. "Casting," by D. V. ATTERTON. Headquarters of The Manchester Literary and Philosophical Society, 36, George Street, Manchester. 6.30 p.m.

10th November

Institution of Plant Engineers, Glasgow Branch. "Planned Lubrication in a Modern Steelworks," by J. STEWART. Scottish Building Centre, 425, Sauchiehall Street, Glasgow, C.2. 7.15 p.m.

15th November

Sheffield Metallurgical Association. "Some Aspects of Hydrogen in Steel," by J. HEWITT. **Joint Meeting with the Royal Institute of Chemistry Local Section.** BISRA Laboratories, Hoyle Street, Sheffield, 3. 7 p.m.

16th November

Institute of Fuel, North Western Section. "Instrumentation," by ELECTROFLO METERS CO. Engineers' Club, Albert Square, Manchester. 2.30 p.m.

18th November

West of Scotland Iron and Steel Institute. "Selection, Testing and Use of Steel for Caterpillar Tractors," by W. SELLARS and W. J. CORMACK. 39, Elmbank Crescent, Glasgow. 6.45 p.m.

22nd November

Sheffield Metallurgical Association. "Some Applications of Castables and Mouldables in the Iron and Steel Industry," by DR. R. W. GRIMSHAW. BISRA Laboratories, Hoyle Street, Sheffield, 3. 7.30 p.m.

23rd November

Manchester Metallurgical Society. "New Aspects of the Electron Theory of Metals," by PROF. G. V. RAYNOR. Headquarters of The Manchester Literary and Philosophical Society, 36, George Street, Manchester. 6.30 p.m.

24th November

Institution of Engineering Inspection, North Western Branch. "Impregnation of Castings," by A. YOUNG. Engineers' Club, Albert Square, Manchester. 7.30 p.m.

29th November

Sheffield Metallurgical Association. "Some Apects of Research for Steel Foundries," by DR. A. H. SULLY. **Joint Meeting with the Sheffield Society of Engineers and Metallurgists.** BISRA Laboratories, Hoyle Street, Sheffield, 3. 7 p.m.

The Influence of Trace Elements on Embrittlement Phenomena in Low-Alloy Steels*

By J. M. Capus, B.Sc., Ph.D., and G. Mayer, B.Sc., F.I.M.†

Work using high-purity materials has made it possible to distinguish between the influence of major alloying elements and of trace elements in causing "350° C. embrittlement" and temper-brittleness in nickel-chromium and nickel-chromium-molybdenum steels. These three elements are not primarily responsible, but the presence of certain minor impurity elements is essential.

TWO types of embrittlement to which low-alloy steels are prone as a result of heat treatment are known, respectively, as "350° C. embrittlement" and "temper-brittleness." Either type of embrittlement may be encountered in a hardened and tempered steel, depending on the heat treatment employed: both have a deleterious effect on impact properties. The two phenomena can be differentiated as follows:—

(*a*) "350° C. *Embrittlement*"

When a hardened steel is tempered in the range 250°–400° C., the resulting room-temperature impact values are inferior to those obtainable by tempering at higher or at lower temperatures. The effect is common to most low-alloy and plain carbon steels, and is associated with intergranular brittle fracture.

(*b*) *Temper-Brittleness*

This type of brittleness may appear in alloy steels after they have been slowly cooled from a tempering temperature above about 600° C., or after being reheated for a prolonged period in the range 350°–600° C. after tempering in a higher range. The embrittlement so induced may result in a lower room-temperature impact value than would be obtained in the same material quenched from a tempering temperature above the embrittling range. Temper-brittleness is not, however, always reflected in a major change in room-temperature impact value, since the primary effect constitutes a displacement of impact-transition to a higher temperature level, which may yet remain below room temperature. This type of embrittlement is accompanied by a change in the mode of brittle fracture, which becomes predominantly intergranular.

"350° C. Embrittlement"

The low room-temperature toughness of steels tempered in the range 250°–400° C. is not associated with impairment of ductility as shown by tensile properties; as tempering temperatures are raised above 200° C. the ductility increases, accompanied by a continuous fall in tensile strength. If no embrittlement occurs, the impact-transition temperature should also fall as the tempering temperature is raised and as the hardness of the steel decreases, but if the steel is prone to embrittlement the transition temperature passes through a maximum after tempering at temperatures of about 350° C. The brittle fractures of commercial steels tempered in the embrittling range are predominantly intergranular.[1]

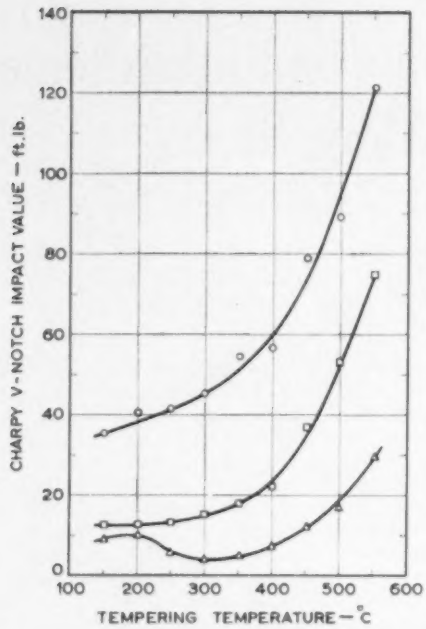
"350° C. embrittlement" is of particular practical significance in the field of high-strength steels, where an optimum combination of tensile strength and toughness is required. The minimum in impact values resulting from treatment at 250°–400° C. usually limits tempering treatments to temperatures outside this range, and precludes the possibility of obtaining the maximum yield-stress values which, in most hardened alloy steels, are obtainable by tempering at 300°–350° C. The restriction on the range of tensile strengths which can be utilised for a given steel is a further factor which often hinders the effective use of these materials.

Factors Influencing "350° C. Embrittlement"

Schrader, Wiester and Siepmann[2] showed that steels containing chromium or manganese are highly susceptible to this form of embrittlement. Plain nickel steels containing 1½ and 5% nickel did not, however, show a definite "impact trough" in room-temperature tests, but it must be noted that the steels used by these investigators were of low carbon content and it is possible that they were not fully hardened. The same workers, studying the influence of aluminium on a chromium-manganese steel, found that if the aluminium content was above 0·04% the "trough" in the impact curves was greatly reduced, and that with about 0·1% aluminium it was completely eliminated. From this they concluded that "350° C. embrittlement" was due to the precipitation of nitride of chromium or of manganese. Riedrich[3] has pointed out that the influence of aluminium was apparent only at room temperature. He found that an aluminium-treated manganese steel showed no "impact trough" when tested at room-temperature, but that tests at −70° C. revealed, in the same steel, embrittlement similar to that found at room temperature in an untreated manganese steel. The view that "350° C. embrittlement" is due entirely to the presence of nitrogen would not explain why an increase in the phosphorus content of a steel can intensify this type of embrittlement.[1]

Alternative explanations have been put forward in terms of the structural changes occurring during tempering of martensite. From a study of the influence of tempering time on development of "350° C. embrittlement," Klingler *et al*[4] suggested that the effect was associated with localised precipitation of cementite platelets at prior austenite grain boundaries, resulting in formation of thin ferrite networks in an otherwise martensitic structure. Other investigators[5] have suggested that grain-boundary precipitation of platelet cementite *per se* was responsible for the embrittlement. According to these theories, all tempered martensitic steels would be expected to show "350° C. embrittlement."

*This paper first appeared in *Das Industrieblatt*, Stuttgart, 1959, **59**, 580–583.
†The Mond Nickel Co., Ltd., Birmingham, England.



Circles ... ... High-purity steel (C 0·28%)
Squares ... ... High-purity steel (C 0·42%)
Triangles... ... ... Commercial-purity steel (C 0·36%)

Fig. 1.—Impact values at 20° C. of hardened and tempered high-purity and commercial-purity 1½% Ni-Cr-Mo steels.

Recent Work on the Influence of Impurity Elements

In view of the possibility that trace elements might exert a major influence on "350° C. embrittlement," a study was recently made in the Laboratory of the Mond Nickel Co., Ltd., of the impact properties of steels made from high-purity materials. The analyses of the raw materials used, which were of the highest purity obtainable, are given in Table I.

TABLE I—COMPOSITION OF RAW MATERIALS

Material	Impurities (Wt.%)	
Carbonyl Iron	Carbon	0·01
	Nickel	0·19
	Oxygen	0·15
	Sulphur, Phosphorus, Tin, Antimony	N.d.
Molybdenum	Silicon, Manganese, Chromium	<0·005
	Antimony, Tin, Copper, Cobalt, Germanium, Gallium	N.d.
Nickel Pellet	Iron	0·041
	Carbon	0·04
	Sulphur	0·001
	Copper	0·003
Electrolytic Chromium	Nickel	0·02–0·03
	Bismuth, Tin, Antimony, Arsenic, Molybdenum, Boron, Vanadium	N.d.
	Manganese	0·005
	Silicon	0·005
	Magnesium	0·005
	Titanium	0·005
	Aluminium	0·005
	Copper	0·001
	Lead	0·001

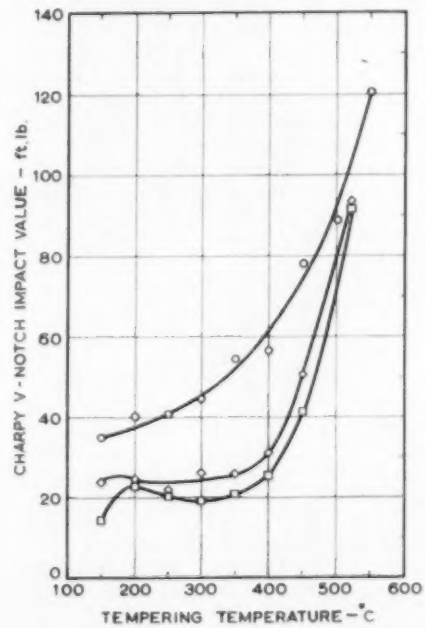
N.d. = not detected.

Steels of the 1½% nickel-chromium-molybdenum type were prepared by vacuum-melting in a high-frequency induction furnace, under a pressure of 10^{-3} mm. Hg, and after processing to ⅝ in. diameter bar and hardening by oil-quenching from 850° C., the steels were tempered for ½ hour at a series of temperatures between 150° and 550° C. Standard Charpy V-notch impact specimens of the hardened and tempered steels were broken at room temperature and at −78° C.

As shown in Fig. 1, curves of impact value *v.* tempering temperature for high-purity 1½% nickel-chromium-molybdenum steels containing 0·28% and 0·42% carbon did not, either at room temperature or at −78° C., display the "impact trough" characteristics of commercial steels.[6] The curve for a similar type of steel, but of commercial purity, is included for comparison.

The freedom of high-purity steels from "350° C. embrittlement" was confirmed by determination of impact-transition temperatures for two further 1½% nickel-chromium-molybdenum steels tempered at temperatures covering a wide range. The transition temperatures of these steels, in the hardened condition, were found to fall continuously as tempering temperatures were raised.

These results suggested that the "350° C. embrittlement" in commercial steels might be due to certain impurity elements, and in the light of these results a systematic investigation was made of the influence of selected impurity elements, as affecting the impact



Circles ... ... Pure steel (C 0·28%)
Diamonds ... ... Sb~0·001% ; C 0·32%
Squares ... ... P 0·023% ; C 0·32%

Fig. 2.—The influence of phosphorus and antimony on the impact values at 20° C. of hardened and tempered high-purity-base 1½% Ni-Cr-Mo steels.

properties of hardened and tempered high-purity-base steels.[7] It was found that phosphorus, antimony, arsenic, tin, silicon, manganese and nitrogen could all induce some degree of embrittlement. Fig. 2 shows room-temperature impact value/tempering-temperature curves for 1½% nickel-chromium-molybdenum steels containing 0·023% phosphorus or 0·001% antimony, together with a similar curve for a high-purity steel. Both these impurity additions induced significant embrittlement, and it is apparent that, if larger quantities of antimony were present in a steel, impact properties could be very badly affected. In contrast to the degree of embrittlement caused by small additions of phosphorus and antimony, the presence of 0·044% or 0·084% of arsenic in the 1½% nickel-chromium-molybdenum steels exerted only a very mild effect.

The steels containing tin examined during this investi-

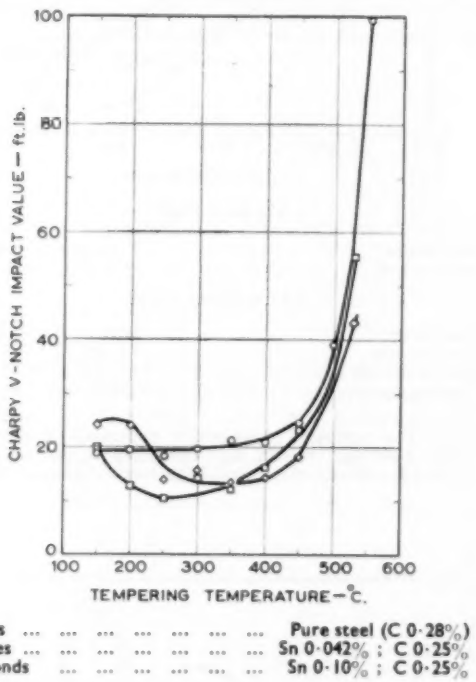

CHARPY V-NOTCH IMPACT VALUE — ft. lb.
TEMPERING TEMPERATURE — °C.
Circles ... Pure steel (C 0·28%)
Squares ... Sn 0·042% ; C 0·25%
Diamonds ... Sn 0·10% ; C 0·25%

Fig. 3.—The influence of tin on the low-temperature (−78° C.) impact values of hardened and tempered high-purity-base 1½% Ni-Cr-Mo steels.

gation had lower carbon contents than the other steels, and, in consequence, the results of room-temperature tests showed little evidence of embrittlement. Tests at −78° C., however, revealed that 0·042% of tin could induce quite a severe degree of embrittlement in steels tempered over a wide range of temperatures (Fig. 3).

The amounts of silicon and manganese added to the high-purity 1½% nickel-chromium-molybdenum steels greatly exceeded the trace amounts of the impurity elements already mentioned (phosphorus, antimony, arsenic, tin), ranging from the amounts normally used for the deoxidation of low-alloy steels to the levels encountered when silicon or manganese is used as a major alloying element. With 0·3% silicon there was a slight embrittling effect, and as the silicon content was

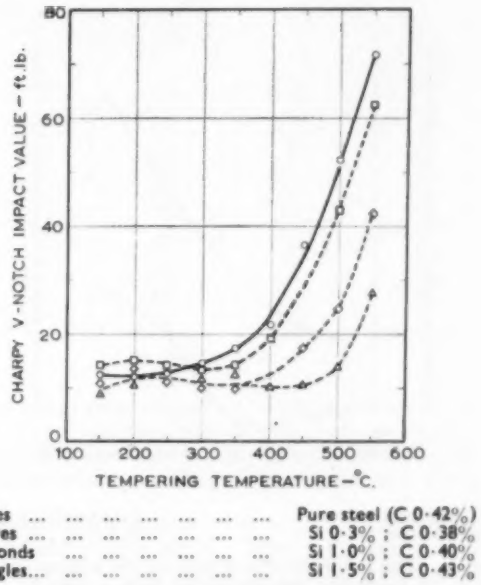

CHARPY V-NOTCH IMPACT VALUE — ft. lb.
TEMPERING TEMPERATURE — °C.
Circles ... Pure steel (C 0·42%)
Squares ... Si 0·3% ; C 0·38%
Diamonds ... Si 1·0% ; C 0·40%
Triangles... Si 1·5% ; C 0·43%

Fig. 4.—The influence of silicon on the impact values at 20° C. of hardened and tempered high-purity-base 1½% Ni-Cr-Mo steels.

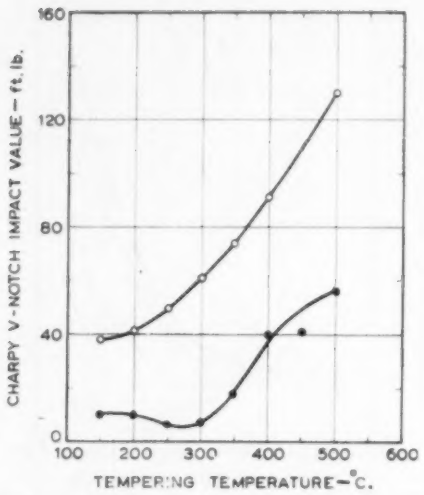
increased, the minimum in the room-temperature impact values was found to be associated with progressively higher tempering temperatures (Fig. 4). This is no doubt associated with the familiar role of silicon in delaying the tempering process. Manganese appeared to produce a general lowering of the impact values after tempering at all temperatures above 350° C. Both the form of embrittlement caused by that element and the high percentage required to produce brittleness suggest that the mechanism of embrittlement associated with manganese is quite different from that operating in the case of trace elements.

The influence of nitrogen was determined on a 3% nickel-chromium steel: room-temperature impact properties of a high-purity steel and of one containing 0·02% nitrogen are shown in Fig. 5. Nitrogen appears to have a severely embrittling effect, particularly when tempering temperatures between 200° and 350° C. are used: i.e., the tempering temperature causing embrittlement is lower than the range required to induce embrittlement in steels containing other impurity elements.

The conclusion of Schrader, Wiester and Siepmann, that the presence of nitrogen in steels could result in "350° C. embrittlement," is thus confirmed: it is clear however, that nitrogen is only one of several elements which are liable to have this effect.

In the steel containing nitrogen the fractures were predominantly intergranular after tempering in the embrittling range, whereas steels containing the other trace elements studied showed little evidence of this type of fracture. The fact that commercial steels also show intergranular fracture when embrittled by tempering in that region supports the conclusion that nitrogen is an important factor in relation to "350° C. embrittlement."

A clearer comparison of the relative influence of the respective trace elements on impact values at various



Open circles ... ... Pure steel (C 0·27%)
Solid circles ... ... N 0·02% ; C 0·29%

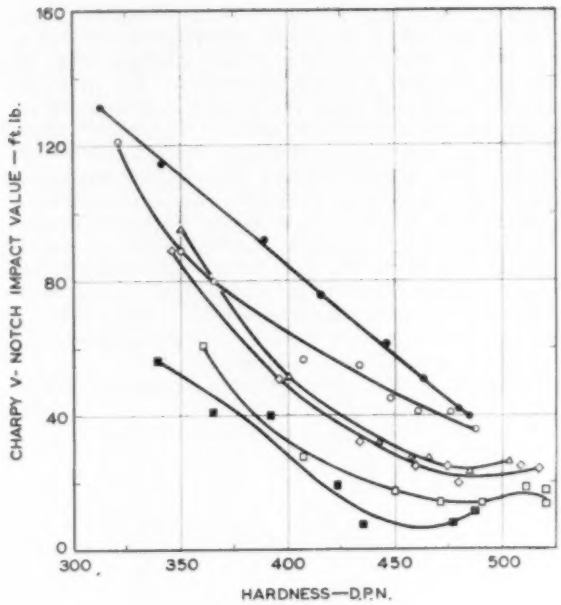
Fig. 5.—The influence of nitrogen on the impact values at 20° C. of hardened and tempered high purity 3% Ni-Cr steels.

strength level, is given by the room-temperature impact value/hardness curves in Fig. 6, relating to quenched and tempered high-purity steels and some steels of similar base composition but containing embrittling elements.

The results of the tests reported justify the conclusion that the impact properties of hardened and tempered commercial low-alloy steels are controlled to a large extent by the presence of impurity elements. The presence of phosphorus and nitrogen is certainly significant in relation to the occurrence of " 350° C. embrittlement," whilst other impurity elements, for which the steels are not usually analysed, may also contribute to embrittlement.

Temper Brittleness

Reduction in toughness, as a result of slow cooling of steels from high tempering temperatures or of reheating in the range 350°–600°, has often been ascribed to the influence of certain major alloying elements. Research in recent years has, however, led increasingly to the view that in relation to temper brittleness the minor elements present may be more important than the major alloying constituents. Thus, phosphorus, antimony and arsenic have been found to exert an influence on the degree of embrittlement,[8,9] and the results of the critical experiments made by Balajiva, Cook and Worn[10] would appear to be decisive. In that investigation, steels of the 3% nickel-chromium type were prepared from high-purity raw materials by a powder-metallurgical technique, and by vacuum-melting, and susceptibility to embrittlement was assessed by determination of the impact-transition temperatures of the steels, in the hardened and tempered condition, before and after reheating at 450° C. for 1,000 hours. In contrast to commercial materials, the high-purity steels showed no shift in transition temperature (Fig. 7) and these findings were confirmed in further work, by Steven and Balajiva,[11] who determined the influence of a large number of minor elements in nickel-chromium and nickel-chromium-



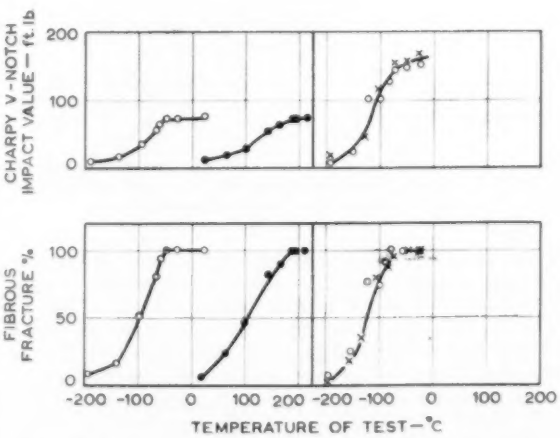
3% Ni-Cr-Steels

Solid circles ... ... Pure steel (C 0·27%)
Solid squares ... ... N 0·02% ; C 0·29%

1¼% Ni-Cr-Mo Steels

Open circles ... ... Pure steel (C 0·28%)
Open squares ... ... P 0·045% ; C 0·32%
Open diamonds ... ... Sb~0·001% ; C 0·32%
Open triangles ... ... As 0·084% ; C 0·31%

Fig. 6.—The influence of impurity elements on the relationship between impact and hardness values at 20° C. of hardened and tempered high-purity-base steels.



Open circles ... ... As hardened and tempered
Solid circles ... ... After 168 hr. at 450° C.
Crosses ... ... After 1,000 hr. at 450° C.

Fig. 7.—The influence of purity on the 450° C. embrittlement of 3% Ni-Cr steels : (left) commercial-purity steel ; (right) high-purity steel.

TABLE II—EFFECT OF TRACE ELEMENTS ON EMBRITTLEMENT AT 450° C.

Type of Steel	Added Element (%)	Charpy V-Notch Impact—Transition Temperature* (° C.)			Maximum Impact Value (ft. lb.)			Shift of Transition Temperature in 1,000 hr. (° C.)
		Initial	After 168 hr.	After 1,000 hr.	Initial	After 168 hr.	After 1,000 hr.	
Ni-Cr	Nil	−60	−60	−60	148	150	152	0
	P 0·008	−110	−50	−20	136	140	150	90
	Sb 0·001	−90	−40	+120	145	100	80	210
	As 0·11	−110	−50	−10	165	174	188	100
	Sn 0·068	+30	+80	+140	120	112	120	110
	Mn 0·70	−70	0	+10	129	120	122	80
	Si 0·74	−80	−50	−40	94	98	98	40
Ni-Cr-Mo	Nil	−70	—	−70	120	—	118	0
	P 0·011	−10	−10	+20	122	106	104	30
	Sb 0·008	−100	−60	+20	134	116	70	120
	As 0·135	−120	−100	−90	158	154	160	30
	Sn 0·068	−90	−60	−60	168	168	157	30
	Mn 0·66	−90	−85	−80	116	114	114	10
	Si 0·69	−60	−30	−20	132	132	132	40

* Criterion: 100% fibrous fracture.

molybdenum steels. The elements were added individually, during vacuum-melting of high-purity material,* and the study covered the effects of the following impurities in the amounts shown:

Phosphorus	0·005–0·040%
Antimony	0·001–0·05%
Arsenic	0·11 –0·23%
Tin	0·034–0·11%
Manganese	0·06 –1·50%
Silicon	0·69 –0·74%
Copper	0·066–0·22%
Nitrogen	0·006–0·019%
Bismuth	0·002%
Cobalt	0·05%
Germanium	0·01%
Gallium	0·01%
Zirconium	0·05%

The embrittling effect of each individual element was assessed on the basis of the rise in impact-transition temperature which occurred when the hardened and tempered steels were reheated at 450° C. for 168 or for 1,000 hours. Transition temperatures were determined by Charpy V-notch impact tests, using as criterion the lowest temperature at which the fracture was 100% fibrous.

The impact data obtained for 3% nickel-chromium steels containing phosphorus, antimony, arsenic and tin are presented in Figs. 8 and 9. Each of these elements caused a rise in the impact-transition temperature of steels which had been reheated at 450° C., and manganese and silicon exerted a similar influence.

Antimony was by far the most severly embrittling element; a mere trace (0·001%) resulted in a rise of 210° C. in impact-transition temperature. Phosphorus, even at levels which would be regarded as very low for commercial steels, produced a significant degree of embrittlement; for example, 0·008% phosphorus caused a rise of 90° C. in the impact-transition temperature after reheating for 1,000 hours at 450° C.; (see Table II). Arsenic, tin, manganese and silicon had a much less potent influence on the embrittlement of the 3% nickel-chromium steels, and, of these elements, silicon and manganese had the least effect. The embrittlement induced by each of the elements mentioned was

* Except where otherwise stated, trace elements were kept to the following limits: Si <0·1%; Mn <0·1%; S ≤0·004%; P ≤0·004%; Al ≤0·06%; V ≤0·01%; Cu <0·01%; As <0·01%; Sn <0·01%; Pb <0·002%; Ti <0·01%; Mg <0·01% N <0·0008%; O ≤0·005%.

The following elements were not detected: Sb, Bi, Co, Ge, Ga, Zr, W, Zn, B, Nb, Te, Th.

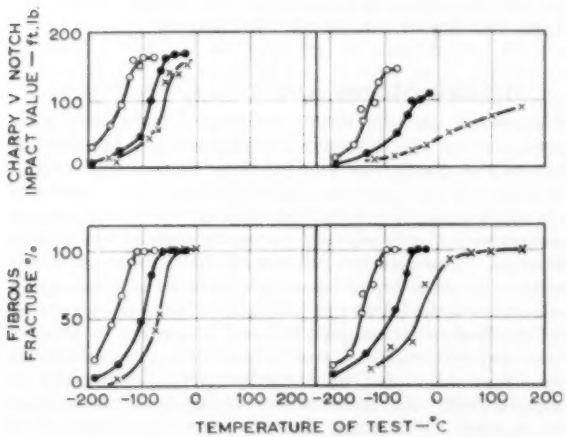

CHARPY V NOTCH IMPACT VALUE — ft. lb.
200
100
0
FIBROUS FRACTURE %
100
50
0
-200 -100 0 100 200 -200 -100 0 100 200
TEMPERATURE OF TEST—°C
Open circles ... ... As hardened and tempered
Solid circles ... ... After 168 hr. at 450° C.
Crosses ... ... After 1,000 hr. at 450° C.

Fig. 8.—The influence of phosphorus and antimony on the impact values of 3% Ni-Cr steels before and after reheating at 450° C.: (left) P 0·008%; (right) Sb 0·001%.

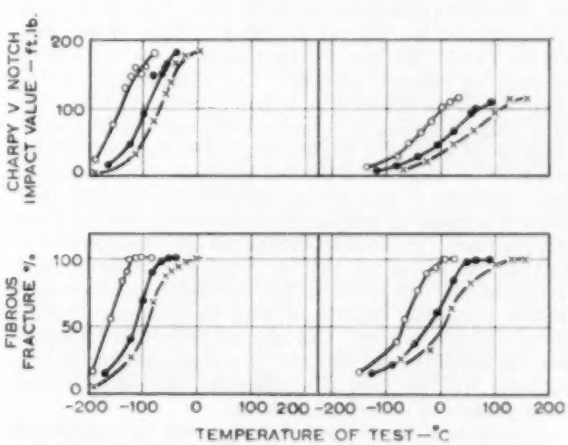

CHARPY V NOTCH IMPACT VALUE — ft. lb.
200
100
0
FIBROUS FRACTURE %
100
50
0
-200 -100 0 100 200 -200 -100 0 100 200
TEMPERATURE OF TEST—°C
Open circles ... ... As hardened and tempered
Solid circles ... ... After 168 hr. at 450° C.
Crosses ... ... After 1,000 hr. at 450° C.

Fig. 9.—The influence of arsenic and tin on the impact values of 3% Ni-Cr steels before and after reheating at 450° C.: (left) As 0·11%; (right) Sn 0·068%.

accompanied by the appearance of intergranular brittle fracture at temperatures below the impact-transition temperature range, and increasing the percentage of the injurious element was in most cases found to increase the degree of embrittlement. For a few of the steels there was evidence (from the transition temperature and the appearance of the fracture) that some embrittlement had occurred during the initial tempering of the hardened steel at 600° or 650° C. Copper, nitrogen, bismuth, cobalt, germanium, gallium and zirconium had no embrittling effect.

The influence of molybdenum on the potency of the embrittling trace elements may be seen by comparing results for nickel-chromium steels with those obtained on nickel-chromium-molybdenum steels (see Table II). In all cases except the silicon-containing steels, molybdenum significantly reduced the degree of embrittlement caused by the impurity elements. Embrittlement was not, however, eliminated by molybdenum, and with steels containing antimony the rise in impact-transition temperature after reheating at 450° C. for 1,000 hours was still considerable.

Conclusion

The employment of high-purity materials in these researches has for the first time made it possible to distinguish between the effects of major alloying elements and of trace elements. The work has shown that the alloying elements nickel, chromium and molybdenum are not primarily responsible for the occurrence of " 350° C. embrittlement " and temper-brittleness, but that the presence of certain minor impurity elements is essential. Some of these elements are invariably present in commercial steels, whilst others may occur in trace amounts and are often not analysed in routine procedures, although their detection presents no difficulty by modern analytical methods.

This survey of some recent advances in the study of embrittlement phenomena in steels is designed primarily to direct attention to the importance of impurity elements. The mechanism by which these elements effect embrittlement is undoubtedly of great interest, and it is hoped that the results reviewed in this paper will stimulate efforts to clarify this question. It is, however, considered that presentation of these data may be even more practically useful if the information provided encourages the development of economic methods for the production of non-embrittling steels by the use of techniques permitting closer control of purity.

Acknowledgment

The authors acknowledge their indebtedness to the Mond Nickel Co., Ltd., for permission to publish this paper.

REFERENCES

1 Schwartzbart, H. and Sheehan, J. P., " Impact Properties in Low Alloy Steels," *Iron Age*, 1956, **178**, Aug. 9, 85–89; Aug. 16, 102–106; Aug. 23, 107–110.
2 Schrader, H., Wiester, H. J. and Siepmann, H., " Embrittlement of Hardened Steels on Tempering at 250°–400° C.," *Archiv Eisenhüttenwesen*, 1950, **21**, 21–27.
3 Riedrich, G., (in discussion of Reference 2), *ibid.*, 27–29.
4 Klingler, L. J., Barnett, W. J., Frohmberg, R. P. and Troiano, A. R., " The Embrittlement of Alloy Steel at High Strength Levels," *Trans. Amer. Soc. Metals*, 1954, **46**, 1557–1589.
5 Lement, B. S., Averbach, B. L. and Cohen, M., " Microstructural Changes in Tempering Iron-Carbon Alloys," *ibid.*, 851–877.
6 Capus, J. M. and Mayer, G., " Impact Properties of High-Purity Nickel-Chromium-Molybdenum Steels," *Jnl. Iron and Steel Inst.*, 1958, **189**, 255.
7 Capus, J. M., " The Influence of Trace Elements on the Impact Properties of Hardened-and-Tempered Low-Alloy Steels," *Rev. Metallurgie*, 1959, **56**, 181–189.
8 Woodfine, B. C., " Some Aspects of Temper-Brittleness," *Jnl. Iron and Steel Inst.*, 1953, **173**, 340–355.
9 Austin, G. W., Entwisle, A. R. and Smith, G. C., " Effect of Arsenic and Antimony on Temper-Brittleness," *ibid.*, 376–386.
10 Balajiva, K., Cook, R. M. and Worn, D. K., " Effects of Trace Elements on Embrittlement of Steels," *Nature*, 1956, **178**, 433.
11 Steven, W. and Balajiva, K., " The Influence of Minor Elements on the Isothermal Embrittlement of Steels," *Jnl. Iron and Steel Institute*, 1959, **193**, 141–147.

United Steel Scholarships

With the object of remaining in the forefront of scientific research and technical advance in iron and steel manufacture, The United Steel Cos., Ltd., are to offer up to ten university scholarships each year, tenable at any university in the United Kingdom. Each scholarship will be worth £500 per annum and its value will not be affected by parental income. The scholarships will be offered to boys proceeding to a university to take full-time courses leading to approved degrees in appropriate branches of science or engineering. The company is also prepared to consider a limited number of applications from students of non-science subjects, recognising that there is a place in industrial management for the good arts graduate. It is intended that the scholarships should provide industrial as well as academic training, and arrangements will be made for successful candidates to receive industrial experience with the company before going up to university and also to undertake vacation work in industry. In addition to the scholarship award, students will be paid a subsistence allowance during these periods of industrial training.

Applications for the scholarships will be considered from students in their final school year who have achieved the necessary academic standard and have also been offered a place at a university. In addition to academic qualifications, the selectors will be looking for character, initiative and independence of mind. On completion of their degree courses, scholars will have the opportunity of joining the company's graduate training scheme, which already has the approval of the appropriate professional institutions.

Booklets and application forms are now available on request to the company and enquiries should be addressed to University Scholarships, The United Steel Cos. Ltd., The Mount, Broomhill, Sheffield, 10.

British Stress Analysis Committee

Following an exploratory meeting on 1st March 1960, arranged by the Institute of Physics, a Joint British Committee for Stress Analysis has been set up in Great Britain. This committee will represent the interests of Great Britain in the field of stress analysis at the periodic meetings of the Permanent Committee which are held in Europe. The principal object of the Permanent Committee, membership of which is open to all west European countries, is the furtherance of international collaboration in the field of stress analysis, and in seeking to achieve this end international conferences will be arranged at four-year intervals. Such conferences will normally be phased with the international congresses on applied mechanics. The Joint British Committee consists of representatives appointed by The Royal Aeronautical Society, The Institution of Civil Engineers, The Institution of Electrical Engineers, The Institute of Marine Engineers, The Institution of Mechanical Engineers, The Royal Institution of Naval Architects, The Institute of Physics and the Physical Society, The Institution of Structural Engineers and the Institute of Welding.

Low Pressure Metallurgy

Vacuum as an Inert Atmosphere

By A. S. Darling, B.Sc.(Eng.), Ph.D., A.M.I.Mech.E.

In the October, November and December, 1959, issues of METALLURGIA, *there appeared an article by Dr. Darling entitled: "Low Pressure Metallurgy—A General Survey." The present article is the second under the same general heading, and the reference numbers follow on those in the earlier article. In dealing with the use of vacuum as an inert atmosphere, the author discusses such aspects as the gas tightness of a vacuum system; contamination during vacuum melting of such metals as iron, nickel and uranium; and vacuum oxidation processes in the solid state.*

INERT gases of commercial quality may contain 0·1% of reactive impurities, which exert, therefore, in the unconstrained condition, partial pressures of the order of 1 mm. Hg. For this reason a poor vacuum usually offers better protection than a good gas cover. Technical difficulties associated with the purification, storage and maintenance of rare gases in a high state of purity usually make it cheaper and simpler, when operating conditions permit, to use vacuum as an inert atmosphere.

Undesirable gas reactions at low pressures occur to an extent which is dependent more upon the real and virtual leak rate of the equipment than upon the degree of vacuum maintained. This can be illustrated by a simple example. Consider the melting of 10 kg. of a reactive metal such as chromium in a vacuum furnace having a volume of 760 litres. If the furnace were gas-tight, and isolated from the pumps at a pressure of 1 mm. Hg., one litre of gas at N.T.P. would be available for reaction with the melt, thus leading to a contamination factor of 0·01%. If the furnace had a slight leak, a diffusion pump operating at a speed of 1,000 litres per second might maintain a pressure of 1 micron over a cold charge. Under such conditions air would be leaking into the furnace at a rate of 79 cc. per minute at N.T.P. If this quantity were to react with the charge during a melting period of 30 minutes, contamination to the extent of 0·03% would ensue. Under such conditions a vacuum of 1 mm. Hg, maintained in a gas-tight furnace would offer better protection than one micron maintained in a slightly leaking container.

Because there is no such thing as a gas-tight furnace and because gas reactions do not in general proceed to the extent predicted by stoichiometrical considerations, undue reliance should not be placed upon illustrations of this type. With the aid of modern techniques the amount of gas leaking into a vacuum system can be reduced to very small quantities. Under such conditions the "oxidising potential" of the equipment is considerably affected by gas evolution from the inside of the system. The parts played by real and "virtual" leakage during vacuum melting and heat treatment are described in a later section.

The Gas Tightness of a Vacuum System

Techniques appear to simplify themselves as those who practise them accumulate experience. A striking aspect of recent vacuum technology is the gradual appreciation that normal engineering processes are, in general, quite adequate for the fabrication of equipment having a very low inherent leak rate. Many of the disappointing results obtained with earlier vacuum furnaces were undoubtedly attributable to a poor standard of gas tightness caused by an inadequate appreciation of the problems involved rather than the lack of refined production techniques.

Leak detection equipment has improved so greatly in recent years that gases permeating into the system from outside can be reduced to volumes negligible in comparison to those evolved actually inside the vacuum chamber. This is particularly true of most metallurgical processes and temperature ranges.

It is justifiable to emphasise that the standard of gas tightness achievable is largely a function of the money spent on leak testing. The maintenance of an unnecessarily high standard of gas tighness is therefore uneconomical. It becomes necessary at this stage to relate tolerable standards of leakage with the different types of metallurgical process. In order to place the discussion on a rational basis a brief digression into the philosophy of leak rates is desirable.

Gas quantities are defined as the product of pressure and volume, and it is usual to arrive at the leak rate of a vacuum system by multiplying the rate of pressure rise in microns by the system volume in litres. The basic gas quantity is referred to as a micron litre. These quantities are arrived at simply by isolating the evacuated system from the pumps and measuring the rate at which the pressure rises. Acceptable rates of leakage should therefore be rationally defined in terms of a maximum rate of pressure rise. In relating acceptable rates of pressure rise with size and function of equipment, two methods of approach may be adopted.

The first method is based upon the assumption that acceptable leakage rates should be related to the surface area of the equipment. Given a certain standard of workmanship a standard permeability per unit surface area of an equipment could be specified. The surface area of similar items of equipment varies as the square and the volume as the cube of the linear dimensions. On this basis we arrive at the following expression:—

$$\frac{dp}{dt} = \frac{k}{l}$$

where $\frac{dp}{dt}$ = permissible rate of pressure rise (microns per hour).

k = specific permeability (micron litres per hour).

l = linear dimensions of equipment.

According to this argument the permissible rate of pressure rise should vary inversely as the linear dimensions

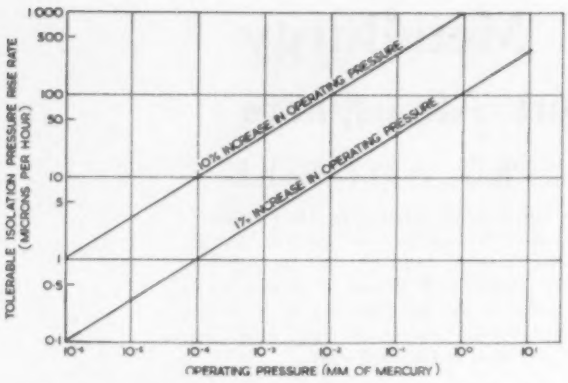


Fig. 1.—Acceptable rates of isolated pressure rise related to the operating pressure of the system.

of the apparatus. It is in fact generally the case that larger items of equipment built in the same manner have a lower rate of pressure rise than smaller items, but the problem is complicated by internal degassing, which has a proportionately greater effect in smaller volumes. A weakness of the system is that it demands an unnecessarily high standard of gas tightness for large items of vacuum plant, and is therefore uneconomic.

The second method of approach involves a consideration of the effect of any leakage on the operation of the particular vacuum process. According to this hypothesis a tolerable leak rate would be one which did not increase the operating pressure above a specified amount. It is helpful to remember that the volume of the equipment employed will vary roughly according to the scale of the process being operated. Since the gases evolved will vary in the same ratio, volume and pumping speed should be directly related.

For a process such as vacuum metallisation, normally operated at a pressure of 10^{-5} mm. Hg, a 10% rise of pressure would be tolerable. The vacuum chamber might be of 200 litres capacity, evacuated at 2,000 litres per second. An acceptable leak rate on such a system would be 0·2 micron litres per second, conveniently specified by an isolated pressure rise rate of 3·6 microns per hour.

Such considerations lead to the hypothesis that an acceptable rate of leakage would be proportional to the volume of the apparatus and could be conveniently specified in terms of a definite rate of rise of pressure, which would be constant and independent of the size of equipment considered. Three great advantages result :—

(1) Acceptable standards of gas tightness can be simply defined in terms of maximum rate of rise of pressure.

(2) An acceptable rate of rise of pressure can be defined for a particular type of process, irrespective of the size of apparatus.

(3) All the components intended for assembly into large equipment can have the same maximum rise of pressure. The rate of rise of pressure in the complete equipment, when assembled, will in general be lower than that of the individual components, due to the elimination of duplicated sources of leakage.

Acceptable rates of pressure rise, based on the foregoing system, are directly linked to a tolerable proportional increase in operating pressure and to the ratio between system volume and pumping speed. The latter ratio is determined primarily by the characteristics of the process being operated, being dependent upon the degree of vacuum required and the total throughput of gas. Certain processes operated at very low pressures may require pumping speeds ten times the furnace volume. At higher pressures, such as those encountered in certain distillation processes, pumping speeds may be only one tenth of the volume being evacuated. Suitable values for pumping speed ratios between these two extremes are imposed largely by the differing characteristics of backing, booster and diffusion pumps. Utilisation of conventional pump speed ratios makes it possible to specify acceptable rates of isolation pressure rise in terms of the foregoing system. Fig. 1, calculated according to such assumptions, relates acceptable rates of pressure rise with the operating pressure of the system. In a system operating at 10^{-5} mm. Hg a 10% rise in operating pressure might be tolerated. This standard of gas tightness could be assured by specifying an isolation pressure rise rate of less than 3·3 microns per hour. On the same basis a 10% increase of operating pressure in a system operating at 100 microns would be obtained even if the rate of pressure rise were 360 microns per hour. This latter value is of course unnecessarily high, and could be reduced by a factor of ten with no added expense.

For most metallurgical work, standards of gas tightness better than 10 microns per hour are rarely required, although this value is fairly easily achieved. Smethurst,[129] for example, remarks that 3·6 microns per hour is a

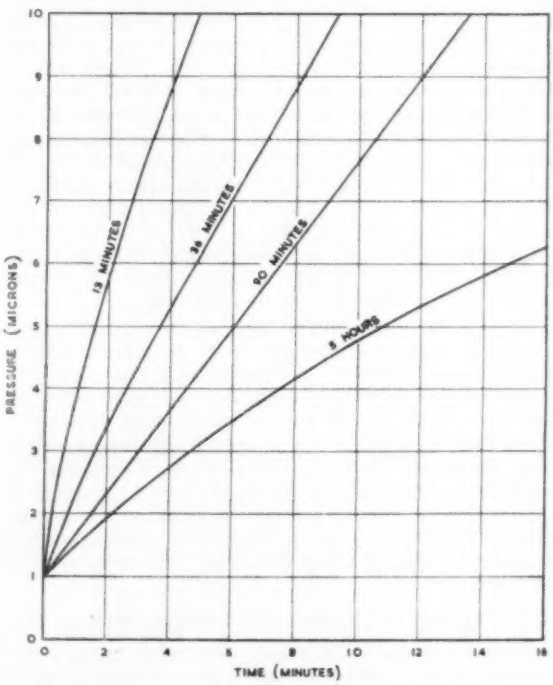


Fig. 2.—Isolated pressure rise curves taken at various stages during the evacuation of a water-cooled stainless steel furnace.

reasonable request not likely to involve much difficulty in manufacture. Higher standards of gas tightness, although possible, are of little value in continuously-pumped equipment, where ambient pressures are comparable with the vapour pressure of the oil in the pumps. Oxidation cannot be completely prevented in any vacuum system, and the oxidation potential of gases and vapours evolved internally is comparable to and in some instances greater than that due to leak rates of the order of 5 microns per hour. Ten years ago Weingartner[130] reported that typical rates of pressure rise in mild steel vacuum tanks ranged from 30 to 50 microns per hour, whilst the average for stainless steel tanks was 30 microns. A recent A.E.R.E. specification[131] on this subject has been based upon standards shown by experience to be reasonable for general use. For vessels up to 1 litre capacity the isolation rate of pressure rise measured in microns per second multiplied by the volume of the vessel in litres should not exceed 0·01. For vessels larger than one litre the isolation pressure rise rate should not exceed 36 microns per hour.

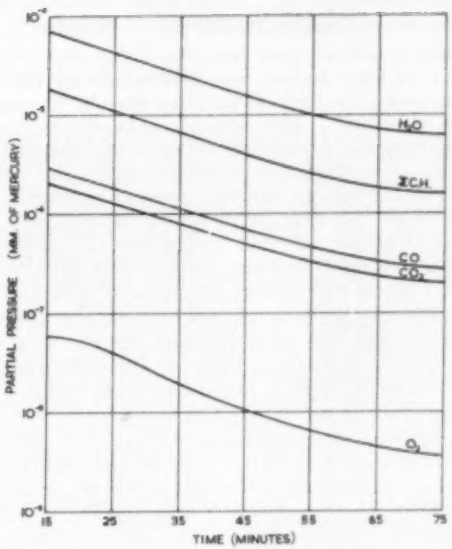
Virtual Leakage

The degassing characteristics of materials used for vacuum processes have been discussed in detail by numerous authors and no attempt will be made to review this work. Observations made during the pump-down period of any vacuum system are sufficient to emphasise, however, that most of the gases removed below 1 mm. Hg come from the walls of the apparatus and from the interior of refractory materials present, rather than from any small leaks which may exist. Fig. 2 illustrates some isolation pressure rise curves taken at various periods during the evacuation of a water-cooled stainless steel furnace operating at a pressure of approximately 5×10^{-5} mm. Hg. These curves illustrate that even after 5–6 hours of pumping the pressure rise rate has not arrived at a constant value and that gases are still being evolved from the furnace walls. Blears and Leck[132] report that the evolution of adsorbed gases from the interior surfaces of a metal vacuum chamber can produce a virtual leak of about 10 micron litres per second per square meter after 15 minutes of pumping. This value falls to 1 micron litre per second after one hour and subsequently by a factor of 2 per hour. Water represents about 75% of the material desorbed from well-cleaned metal surfaces.

Outgassing of metal surfaces usually occurs at fairly low pressures, and the time required to pump down to one micron does not always reflect the quantities of adsorbed gas. At lower pressures, however, the pump-down times afford a satisfactory indication of the quantities of gas taken up during exposure of the furnace interior to atmospheric pressure. The data in Table I, taken from Weingartner[132], illustrate this effect in a pronounced manner. The tests were made on a cylindrical stainless steel tank 4 ft. in diameter and 4 ft. long. After exposure to the atmosphere for 75 minutes the time taken to pump down from 1 to 0·1 microns was approximately 100 times that required when the tank had been previously outgassed.

TABLE I.—EFFECT OF EXPOSURE TIME UPON PUMPING DOWN TIME FOR A PREVIOUSLY OUTGASSED TANK

Exposure to Air	Time to Pump from 1·0 to 0·1 micron (sec.)
Nil	7 (calculated for clean tank)
Pressure increased from 0·1 to 1·0 microns and immediately pumped	13
Atmosphere 5 minutes	777
Atmosphere 75 minutes	1,430



(Courtesy of Journal of Scientific Instruments.)

Fig. 3.—Changes of partial pressure observed during the initial evacuation of a stainless steel vessel with an oil-diffusion pump (after Blears).

A knowledge of the composition of gases and vapours evolved during the outgassing of a vacuum system is obviously of great value. Systematic investigations of this problem have been made by several workers. Strong[133] has described what he refers to as a "throughput" gauge which permitted the collection and, if necessary, analyses of gases extracted from a baked metal vacuum system. This system was evacuated by a mercury pump trapped with dry ice and liquid air. The results obtained were of interest chiefly in connection with the process of vacuum metallisation.

The mass spectrometer offers a more convenient approach to the problem of residual gases. The first "vacuum analysers" were employed on the Manhattan Project. These items of equipment were semi-quantitative in action and suitable for continuous operation. They utilised a cold cathode ionisation gauge as a positive ion source for a mass spectrometer which separated the gases in the vacuum system according to mass up to a maximum of 50[134]. Such instruments were later developed into routine helium probe leak detectors. General purpose instruments of more recent design offer ideal facilities for studying the outgassing processes of dynamically-pumped vacuum systems.

Typical changes of partial pressure observed by Blears during the initial evacuation of a stainless steel vessel by an oil diffusion pump are illustrated in Fig. 3[135]. The vacuum chamber had been opened to the atmosphere for 3 hours and then evacuated. The curves illustrate the ease with which air can be removed from a vacuum system. After 20 minutes the oxygen pressure was less than 10^{-7} mm. of Hg.; after 1 hour it was 10^{-8} mm. Hg. and still falling. Air accounted for less than 0·5% of the material in the gas phase. Water

vapour represented 70% of the gases extracted, hydrocarbons accounting for most of the remainder.

Blears concluded that the rate of removal of matter from a vacuum system was determined by the forces binding molecules to surfaces rather than by the pumping speeds employed. After several weeks of pumping with baking periods of at least 48 hours an ultimate total pressure was reached. Depending upon the pumping fluid employed, the ultimate partial pressure of air varied from $0{\cdot}5\text{–}1{\cdot}8 \times 10^{-9}$ mm. Hg. Because such partial pressures are still well above the dissociation pressures of most metallic oxides, oxidation will still occur, even in the best attainable vacuums.

Measurements of the observed rate of fall of pressure indicated that the time constant for the removal of residual gases during the initial evacuation process was only 1/4,000th of that calculated from the volume of the system and speed of pumping.

Two surprising conclusions resulted from this work. Firstly, it was found that considerable differences in the methods and materials employed for the construction of vacuum systems had little influence on the ultimate vacuum analysis except where a high baking temperature was employed. In all trapped systems the most important residual gas was water. Although the residual hydrocarbon pressure was rather higher for oil-pumped than for mercury-pumped systems, the difference was not pronounced.

The second conclusion was that the presence of a cold trap had a deletrious effect upon the rate of removal of water vapour from a vacuum system. The water was transferred to the cold surfaces from which it re-evaporated. The ultimate water pressure attainable in a trapped brass or stainless steel system pumped with one of the Apiezon fluids was in the range $9\text{–}25 \times 10^{-9}$ mm. Hg.

To be continued

REFERENCES

129 H. Smethurst, "Leak Detection and Some Allied Problems," 1949, Metropolitan-Vickers, Manchester 17.
130 H. C. Weingartner, *Ind. Eng. Chem.*, 1948, **40**, 780.
131 A. H. Turnbull, *Vacuum*, 1955, **5**, 131.
132 J. Blears and J. H. Leck, *Vacuum Physics*, 1950, (*J. Sci. Inst.* Supplement No. 1), 20.
133 J. D. Strong, *Vacuum*, 1952, **2** (2), 111.
134 A. Guthrie and R. K. Wakerling, "Vacuum Equipment and Techniques," McGraw Hill, New York, 1949, p190.
135 J. Blears, *Vacuum Physics*, 1950, (*J. Sci. Inst.* Supplement No. 1), 36.

New Electron Beam Melting Plant

Discharge Difficulties Overcome by Heraeus

THE results obtained in the laboratory by melting metals in high vacuum by means of electron bombardment have shown the technique to have industrial possibilities, but the processes previously used for electron beam melting were not very suitable for application on an industrial scale. As a result of sudden evolution of gas from the melt, or of an appreciable amount of metal vapour, high intensity glow discharges are produced between the electron emission system, which is at a high negative potential, and the melt, which acts as the anode.

These discharges make it necessary to interrupt the operation, which has a harmful effect on the melting process.

After many years of development work, the Vacuum Metallurgical Division of Messrs. W. C. Heraeus, of Hanau, has succeeded in evolving a new method of electron beam melting in which these difficulties are overcome. This method is based on producing and accelerating the electrons in a separately evacuated chamber and then focusing them so that they leave through a narrow aperture as a parallel or slightly divergent beam. Important advantages are achieved as a result of this arrangement. In the first place, the melting takes place in a field-free chamber (the passage of the lines of force through the narrow aperture is so small as to be negligible): this means that the ions formed as a result of electron impact are not accelerated, and consequently no glow discharge can develop. In the second place, in the event of a great deal of gas being evolved during the melting operation, only a small quantity of gas can pass through the aperture into the beam production chamber. This rules out the formation of high-intensity glow discharges, and interruptions of the melting process are thus avoided.

In addition to these two over-riding advantages there are others. Since the electrons already leave the gun with a high rate of energy, and since the material to be melted does not itself act as an accelerating electrode as has been the case hitherto, it does not need to possess any electrical conductivity. This means that in addition to metals it is now possible to purify and degas by melting in high vacuum many non-conductors, such as ceramic materials, and also semiconductors such as are used in the manufacture of transistors. Furthermore this electron gun also makes it possible to carry out addition melting very satisfactorily, by continuously feeding granular or sponge material to a water-cooled copper crucible in which a liquid melt is maintained by electron bombardment.

In order to make these new possibilities accessible to metallurgical research workers and to allow accurate investigations of the suitability of the various electron beam melting processes, Messrs. Heraeus have developed a large all-purpose laboratory plant. In this vacuum melting plant it is possible to use not only the high-capacity electron beam gun, but also the electron production systems which have generally been used hitherto, so that every process of electron beam melting known today can be carried out with this equipment. These include the drip melting, addition melting and button melting methods, as well as the various methods of zone melting both with and without crucible.

This new development has aroused keen interest in technical circles throughout the world. Since July 1959, when Messrs. Heraeus started up the first electron beam melting plant at the Research Institute for Precious Metals and Metallurgical Chemistry (Schwaebisch-Gmuend), contracts have been concluded with a number of the leading centres for atomic and metallurgical research. Today electron beam melting installations are being built with an output of between 5 and 200 kW.

Better Gauge in Metal Strip Production

Further Step in Automatic Control

A NEW device for automatically controlling the gauge of cold rolled metal strip has been developed by English Electric. Experience with the first installation shows that it makes several times the amount of gauge adjustment as the operator normally makes by hand. Besides giving a more uniform product the device also indirectly increases production by freeing the operator from constant supervision of the gauge. He can change his coils more quickly and thus put more through the mill.

The device can be used for mills of any width, reversing or non-reversing. It is also possible to combine it with the automatic slow-down equipment which English Electric has developed for slowing down a cold reversing mill at the ideal time for minimising "thick end" waste. This is the third major automatic control device the company has produced for the metal industry in the last eighteen months. The other is for the automatic programming of rolling operations.

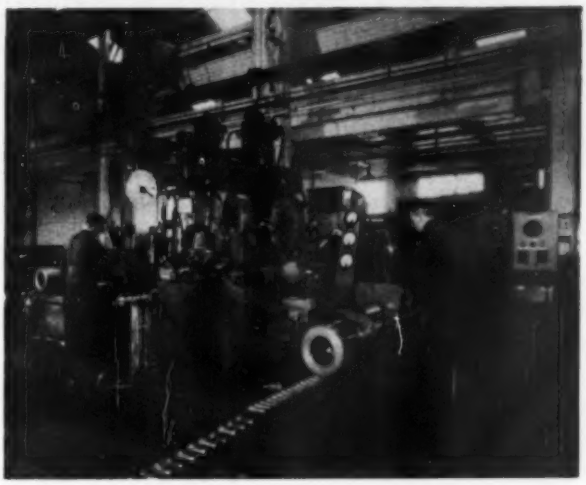
Three mills in the Midlands have been fitted with automatic gauge control, one of them at I.C.I. Metals, Witton, Birmingham. The three mills are rolling copper and brass for the motor car industry. During the summer a mill at Firth-Vickers Stainless Steels, Ltd., Sheffield, designed for rolling stainless steel strip up to 12 in. wide was also fitted with this device.

Method of Operation

The system consists of a flying micrometer, a control panel and the main control cubicle. The flying micrometer, mounted at the edge of the strip, measures the gauge of the rolled material. On a reversing mill a micrometer is mounted on each side of the rolls, and the intended gauge is registered on the front of the micrometer.

The operator sets up his tolerances on the control panel, which is conveniently mounted near the mill. Generally this is done by a multi-position switch, tolerances of $\frac{1}{4}$, $\frac{1}{2}$, 1 and $1\frac{1}{2}$ thousandths of an inch being typical figures, but others can be provided. On automatic control a continuous signal is transmitted to the control cubicle, which may be located wherever desired in relation to the mill. When the error is greater than two thirds of the tolerance setting the screw-downs are operated and the distance between the rolls adjusted. For a reversing mill the control cubicle contains three computing amplifiers, one for each of the two flying micrometers and one as a spare. The screw-down operation is initiated by high speed contractors.

When the mill is rolling slowly, that is up to a critical speed, a sampling control system is used. After an error has been corrected an electronic time delay ensures that the screw-downs do not operate again until the corrected gauge has passed through the flying micrometer. This prevents the system "hunting" for the correct gauge. When the speed is greater than the critical speed, the system changes to continuous control under the automatic operation of a relay in the control cubicle. Hence the fastest correction possible is obtained with maximum stability.



A typical installation of the English Electric automatic gauge control system on a non-ferrous strip rolling mill. The control panel is on the extreme right.

Incorrect setting of the flying micrometer, failure to apply the micrometer to the strip, a break in the strip, or the running of the "thick end" through the flying micrometer would all show an artificial gauge error. This would cause incorrect and possibly dangerous operation if the automatic gauge control were allowed to respond. An excess error relay immediately prevents this and manual control is made available to the operator. Manual control is always available whether automatic gauge control is selected or not.

Stelvetite Wall Facing in Workshop

STELVETITE, the plastic-coated sheet steel produced by John Summers and Sons, Ltd., of Shotton, Chester, has been used to panel the inside walls of a recently completed single-storey building at Elm Works, Ltd., engineers of Summerstown, London, S.W.17. The building comprises 10,000 sq. ft. and was erected as a workshop to cope with an overflow from the sheet metal working and packing departments, and also to serve as a storage department and loading bay. It is constructed in precast concrete with electrically-heated floors and double glazing on the windows, the frames of which are in aluminium.

The workshop was designed with the object of achieving maximum lighting and to ensure minimum maintenance. The inside wall facing, which is in white Stelvetite with a smooth glossy surface and trimmed with wooden beading, helps to achieve the desired lighting effect and lends itself to easy maintenance. A 2 in. insulation material separates the Stelvetite from the brickwork. A large sliding door at one end of the building is also faced with Stelvetite. The outside wall of the building is clad with vitreous-enamelled panels, mauve in colour, and fabricated from John Summers' enamelling-grade steel sheet.

High Speed Forming of Metal Plates

One-Twelfth Scale Tests With Explosives

FOR some time now articles have been appearing in the technical press on the high-speed forming of metal plate by the use of high explosives, compressed air, and the underwater discharge of a high-voltage spark. In order to obtain information on the first named method, equipment was prepared at the Crayford Works of Vickers-Armstrongs (Engineers), Ltd., and explosive charges at Thames Works, to enable experiments to be carried out.

To minimise expense, and at the same time to make the investigation as realistic as possible, it was decided to attempt to produce a one-twelfth scale model of the dome end of a pressure vessel, as shown in Fig. 1. The blanks used were of 20 S.W.G. (0·036) in. bright mild steel plate, and the high explosive charges were Tetryl (C.E.).

Experimental Equipment

Fig. 2 shows diagrammatically the equipment finally used to produce satisfactory results. It comprises a mild steel die and pressure plate, a vacuum pump, and a thin sheet metal cylinder, about 16 in. high. In use, the cylinder is attached to the upper surfaces of the blank by waterproof adhesive tape, and a thin film of grease is applied to the upper surface of the die, to provide an air-tight joint, before the blank is placed on it. Next, the pressure plate is fitted, and the explosive charge suspended in the cylinder, which is then filled with water. Finally, air is evacuated from under the blank before the charge is detonated.

In the course of the experiments, charges varying in weight from 30 grains to 80 drams were used, and they were located at from 2½ in. to 8 in. above the centre of the blank. Also, the charges were made either cylindrical or hemispherical in shape. It appeared that the latter gave the most satisfactory results, although the evidence was by no means conclusive. It was found that, as with conventional press working, the pressure

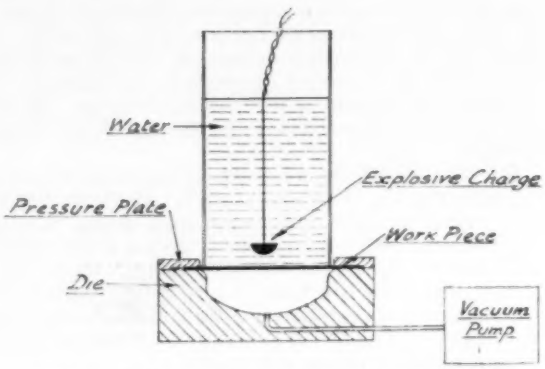


Fig. 2.—Equipment used for explosive forming.

plate is essential to prevent wrinkling of the plate. Indifferent results were achieved with a vacuum of 24 in. of mercury, the residual trapped air in the die causing dents in the dome ends. It was finally established that very satisfactory results could be obtained by using hemispherical charges of 400 grains, located 2½ in. above the centre of the blank, a vacuum of 29 in. of mercury, and ¼ in. entry radius on the die. The dome ends so produced varied extremely little dimensionally, there being virtually no spring-back of the material, and the finish was very good. Further, there was relatively little change in the thickness of the finished material, the maximum reduction being about 0·003 in. This, presumably, can be attributed to the explosive force being applied almost instantaneously over the whole surface of the blank, whereas in conventional press work there is a concentration of stress at the nose of the punch. Fig. 3 shows a formed dome when extracted from the die, and Fig. 4 after being trimmed off.

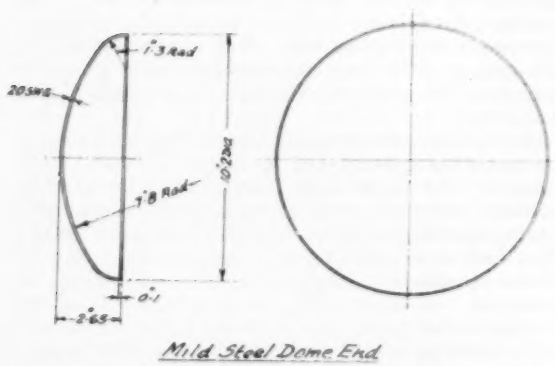


Fig. 1.—Dimensions of one-twelfth scale model of pressure vessel dome end.

Advantageous in Certain Cases

Whilst explosive forming cannot compete with press working in large quantity production of components of normal materials, it can be economically attractive if small quantities are required, more particularly if the components are to be of good finish and dimensionally closely toleranced. Only a female die is required, and it is reported that good results have been obtained with wood, plastic and concrete dies, depending on the number of components required and the finish and dimensional requirements. Also, it has been stated that whilst some special alloys used in the production of components for guided missiles and very fast aircraft have proved unsatisfactory for cold working, they can be shaped by explosive forming. Components that have been partially pre-formed by welding parts together can be finished formed by explosive forming without damage to the weld. Practical considerations

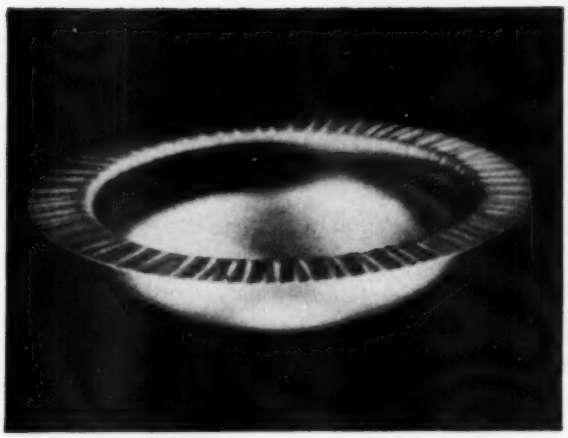


Fig. 3.—Explosively formed dome as extracted from the die.

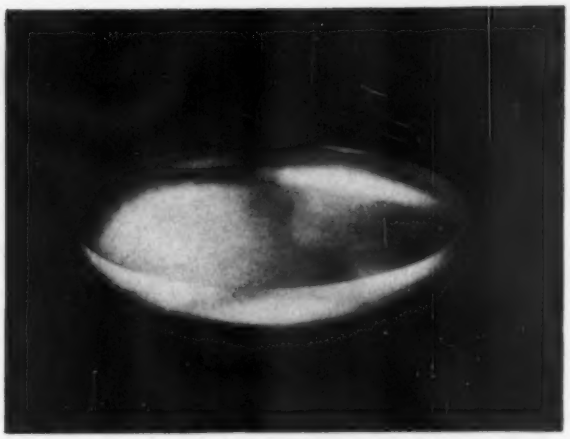


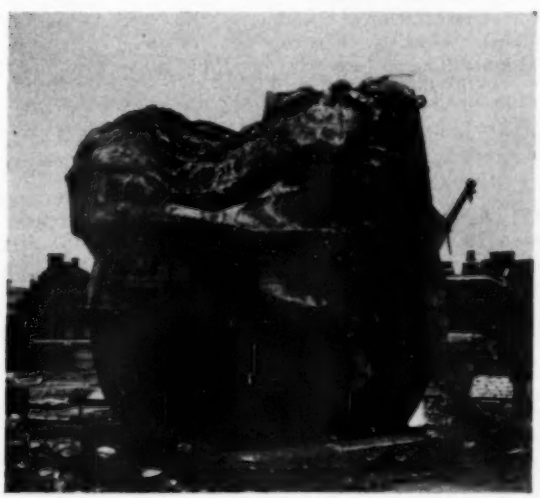
Fig. 4.—Explosively formed dome after trimming.

apart, there would appear to be no limit to the size of plate which could be worked; more precisely, the regular shaping of components from $\frac{5}{16}$ in. thick mild steel has been reported.

Although explosive forming is a relatively new technique, it would appear that it is sufficiently practicable to warrant the consideration of designers and production engineers.

Powder Cutting Copper Vats

DURING demolition of a London brewery recently, seven spherical copper beer vats were dismantled and salvaged through using oxy-acetylene powder cutting equipment. The operation, carried out at the Stag brewery of Watney, Combe Reid & Co., Ltd., was completely successful although other methods had failed. Each vat, standing nearly 20 ft. high and weighing 14 tons, was supported by a heavy copper base $\frac{3}{8}$ in. thick. Normal skin thickness of the spherical container was $\frac{1}{4}$ in., with riveted lapped joints up to $1\frac{1}{4}$ in. thick. Because normal cutting and fracturing methods failed to reduce the vats to manageable proportions, the Sales Technical Service Department of British Oxygen Gases, Ltd., Cricklewood, was consulted and powder cutting was carried out. A high cutting speed was maintained using Saffire oxy-acetylene powder handcutting equipment, manufactured by British Oxygen Gases. Sections measuring about 12 ft. by 4 ft. were removed from the main body of metal for easy handling.



One of the 16 ft. diameter copper vats.

In the powder cutting process a finely divided iron-rich powder is conducted separately to the reaction zone by compressed air or nitrogen. Combustion of the iron powder increases the temperature of the reaction, thereby increasing the fluidity of the refractory oxides, which are removed by a combined melting and fluxing action and, to some extent, by an eroding action of the iron particles. When dealing with copper and copper alloys, powder cutting appears to be a melting action, coupled with the eroding action, rather than true oxygen cutting.

Hardenability of Carburised Steels

NEARLY ten years of research, which indicates that the hardenability of both case and core of carburised steels is essential for the proper selection of the optimum grade and control of its processing for a specific part, is summarised in a book, "Atlas, Hardenability of Carburised Steels," published by Climax Molybdenum Company, a division of American Metal Climax, Inc. For many years it was believed that core hardenability alone was needed to insure adequate case hardenability. Research, however, has disproved this concept with evidence that equal additions of carbon do not have the same effect on the hardenability of base compositions. This is documented in the new book with more than 125 charts which show the effect of cooling rates and distance from end of specimens on the Rockwell hardness of a number of carbon, molybdenum, nickel-chromium, nickel-chromium-molybdenum and other steels.

The Fabrication of Boron by Powder Metallurgical Techniques

By P. Best*, B.Sc., and S. R. Twigg†, A.I.M., A.I.Ceram.

An investigation into the fabrication of boron into shapes, with a view to the use in nuclear reactors of control rods of this material, has shown that boron-rich alloys containing about 10 wt.-% of such metals as nickel, copper and manganese, can be fabricated by a simple hot pressing technique. The bulk density of the compacts is suitable for certain types of nuclear reactor.

NUCLEAR reactors require control rods which function by limiting the availability of neutrons. A suitable control rod will consist of an element of high capture cross-section which will readily absorb neutrons and for this purpose boron isotope B^{10} is highly effective. The fabrication of boron into shapes with a high boron density has been a rather difficult task. Stoke[1] and Wellborn[2] investigated the use of boric oxide, lead borate, and moulding resins. Weintraub[3] developed an arc furnace incorporating a boron container in which boron rods could be formed. Tiede and Birnbraüer[4] heated powdered boron in a cathode ray vacuum furnace, and stated that the material could be purified and melted.

Boron is a common element, solid at normal temperature and pressure, but whose properties and structure are not clearly understood, due mainly to the considerable difficulties encountered in the preparation of high purity material. At high temperatures boron is extremely reactive, and it is difficult to find a refractory material with which it is compatible. It does not readily undergo self-diffusion and, as a result, sintering of powdered material is virtually impracticable.

Structural investigation on boron has proved difficult due to the low scattering power for X-rays. Rollier[5] reports that there are probably 90 boron atoms per unit cell, which makes it one of the largest unit cells of the elements. There are many reports of its great hardness, metallic lustre, conchoidal fracture and large positive resistance coefficient, and these properties indicate the hybrid character and unique properties of the element.

*Formerly U.K.A.E.A. Culcheth.
†R and D Branch, D and E Group, U.K.A.E.A., Culcheth.

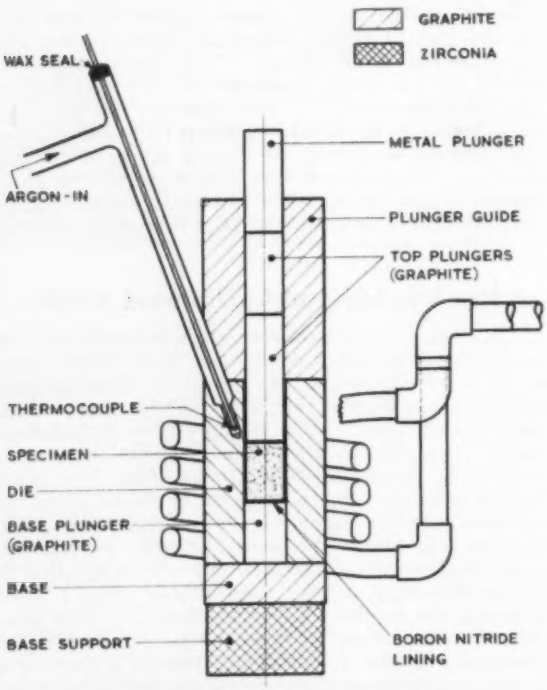


Fig. 1—Details of boron die assembly

Preliminary Work

The nuclear characteristics of boron make it a suitable element for the control of neutron flux, and for this purpose it is an advantage for the control element to have close dimensional tolerances and a high boron density. With these requirements in view it was decided to investigate the fabrication of boron by hot pressing boron powder, using a metallic addition which would fulfil the triple purpose of (*a*) acting as a "plastic" phase during the compacting operation, (*b*) combining with the boron to form a boride, thereby retaining the boron concentration at a high level, and (*c*) rendering the compact less brittle than that of pure boron, to enable final machining to be carried out if necessary.

Materials Used.

(1) Commercial boron powder of −400 mesh and 95% purity with magnesium and oxygen as the principal impurities.

(2) Metal additions of nickel, aluminium, copper, silicon, tin, silver and manganese in powder form of −320 mesh and high purity.

(3) Boron nitride powder of > 99% purity.

Hot Pressing Unit.

The die assembly is shown diagrammatically in Fig. 1, dies and plungers being of high density graphite. The coil terminals were brought out over the top of the box and were connected to a 25 kVA., 10,000 c./s. motor generator set (Figs. 2 and 3). The graphite die stood on a 1 in. thick graphite block, which in turn stood on a zirconia block. The Syndanyo box was filled with −300 mesh alumina packing powder. A graphite plunger

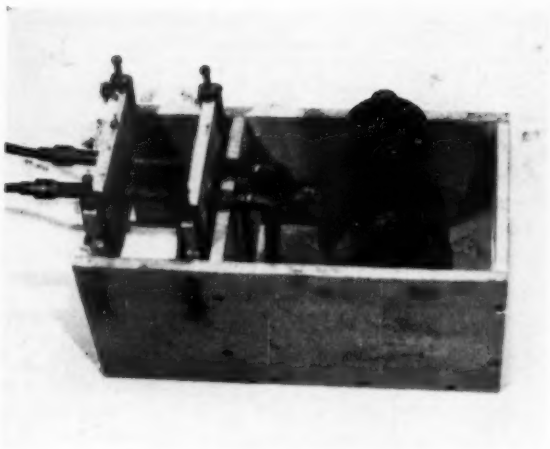


Fig. 2—Boron die assembly

guide was mounted on top of the die, and the load transmitted through a Vital steel plunger working partially within the plunger guide. A thermocouple hole of controlled depth was drilled into the die body, using a guide to ensure consistency in the location of the hot junction. A tungsten-molybdenum couple was used, the junction being either welded or made simply by twisting the wires together. The couple was carried through an alumina tube which terminated $\frac{1}{4}$ in. below the top face of the die; the couple itself continued to the base of the hole. During a heating cycle the couple was shrouded in argon which was fed down the alumina tube at a constant rate of 5 cu. ft./hr. Limited calibration of this couple, up to 1,700° C., was effected by incorporating a 5% Rh-Pt/20% Rh-Pt couple in a similar position.

Operating Details

Additions of nickel, aluminium, copper, silicon, tin, silver and manganese were made within the range 7–15 wt.-%. The powders were mixed by tumbling, before cold compacting at 6 tons/sq. in. into 1 in. diameter compacts weighing 20 g. During hot pressing at 1 ton/sq. in. it was observed that reaction between the graphite die and the boron slug commenced at about 1,500° C. This resulted in a very hard boron carbide skin on the compact and strong adhesion to the die walls. Tungsten, molybdenum, niobium, BeO, ThO_2, ZrO_2, Al_2O_3, MgO and $CaZrO_3$ were tried as interlayers to prevent the reaction of boron with graphite. All the oxides reacted, presumably due to the very high stability of boron monoxide at high temperatures, and the metals tungsten and molybdenum also reacted, whilst niobium became highly embrittled.

Boron nitride was found to be a compatible material following the work of Weintraub.[3] It was used as a mould wash, as a tamped powder, as a cold pressed sleeve and as a hot pressed sleeve. The last three were suitable at a thickness greater than $\frac{1}{16}$ in.; below this, abrasion resulted in boron-graphite contact. For the latter reason, mould wash offered little or no protection.

The compressed boron metal compact and the tamped boron nitride liner swelled appreciably after removal of the restraining die or metal former. Difficulties due to this swelling were circumvented by filling the graphite die as quickly as possible.

Protection for the ends of the boron-nickel slug was obtained either by dusting boron nitride on to the lower graphite plunger and the top of the boron/metal compact, or by pressing boron nitride end caps, $\frac{1}{16}$ in. thick, onto the compact during the cold compacting stage.

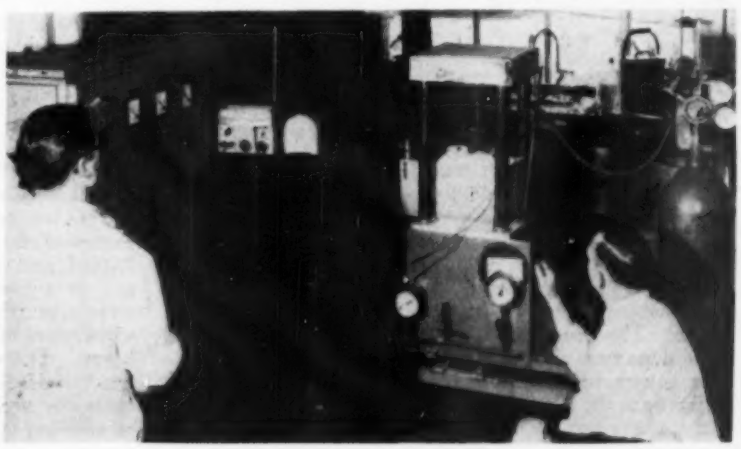


Fig. 3—Hot pressing unit in operation.

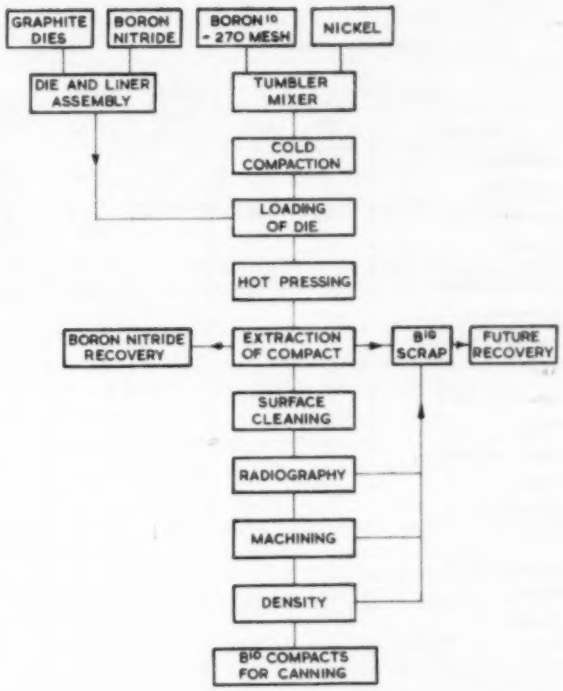


Fig. 4—Production flow sheet.

TABLE I—DETAILS OF COMPACTS MADE FROM VARIOUS MATERIALS

Cold Pressed Compact				Hot Pressing Conditions		Hot Pressed Compact					
Composition			Compact Pressure (tons/sq. in.)	Pressure Applied (lb./sq. in.)	Approx. Temperature (° C.)	Density (g./cc.)	Boron Density (g./cc.)	Boron Concentration (%)	True Boron Density (g./cc.)	True Boron Concentration (%)	Appearance
Material	Wt. %	% Purity									
Amorphous Boron	90	85	17·5	3,360	1,800	2·164	1·947	83·6	1·655	71·1	Porous
Aluminium	10	—									
Amorphous Boron	90	85	17·5	3,360	1,900	2·485	2·236	96·01	1·901	81·61	Vitreous but friable.
Aluminium	10	—									
Hydrogen Treated "N.M." Amorphous Boron ..	90	85	17·5	3,360	1,900	2·49	2·249	96·5	1·911	86·85	Vitreous but friable.
Aluminium	10	—									
Amorphous Boron	80	85	17·5	2,550	1,000	2·206	1·765	77·5	1·50	65·88	Porous
Nickel	20	—									
Amorphous Boron	80	85	17·5	3,360	1,900	2·56	2·048	87·9	1·741	74·72	Vitreous and whole.
Nickel	20	—									
Amorphous Boron	85	85	17·5	3,360	1,900	2·51	2·126	91·2	1·807	77·52	Vitreous but chipped
Nickel	15	—									
Amorphous Boron	90	85	17·5	3,360	1,900	2·607	2·346	100·00	1·993	90·00	Vitreous and whole.
Nickel	10	—									
Elemental Boron	90	95	17·5	3,360	1,900	2·557	2·301	98·74	2·185	93·80	Vitreous and whole.
Nickel	10	—									
Elemental Boron	90	95	17·5	3,360	1,900	2·566	2·309	99·09	2·193	94·12	Vitreous and whole.
Nickel	10	—									
Amorphous Boron	96	85	17·5	3,360	1,900	2·425	2·255	96·78	1·917	82·26	Vitreous but chipped.
Silicon	4	—									
Elemental Boron	90	95	17·5	3,360	1,900	1·746	—	—	—	—	Porous.
Silver	10	—									
"E39" Boron	90	88	17·5	3,360	1,900	2·55	2·294	98·42	2·019	83·66	Vitreous and whole.
Nickel	10	—									
"E43" Boron	90	91·7	17·5	3,360	1,900	2·277	2·049	87·9	1·879	80·6	Vitreous but cracked.
Nickel	10	—									
Amorphous Boron	87	85	17·5	3,360	1,900	2·71	2·304	98·8	1·958	83·98	Vitreous but chipped.
Copper	13	—									
Amorphous Boron	90	85	17·5	3,360	1,900	2·598	2·338	> 100	1·95	90	Vitreous but cracked.
Copper	10	—									
Amorphous Boron	90	85	17·5	3,360	1,900	2·58	2·322	99·64	1·973	84·69	Vitreous but cracked.
Manganese	10	—									
Amorphous Boron	85	85	17·5	3,360	1,900	2·618	2·224	95·48	1·89	81·15	Vitreous but chipped; some segregation of tin.
Tin	15	—									
Amorphous Boron	93	85	17·5	3,360	1,900	2·461	2·289	98·22	1·95	83·49	Vitreous but friable.
Tin	7	—									
Amorphous Boron	85	85	17·5	3,360	1,900	2·617	2·224	95·46	1·89	81·13	Vitreous but chipped.
Manganese	15	—									

The hot pressing unit was designed for flexibility so that separate units could be individually prepared and then slid into the press for hot forming. After pressing, the unit was removed from the press and allowed to cool to room temperature, a good flow of water being maintained through the induction coil during cooling. Thus the production rate was governed by the heating-pressing cycle. The production flow sheet is shown in Fig. 4. The slugs were pressed out at a pressure of a few pounds per square inch. A certain amount of boron nitride adhered to the compact, but this was easily removed with an abrasive hand tool.

Physical Properties

Bulk densities were determined by immersion in water and the true boron density was calculated from the known purity of the starting materials. These are given in Table I, and they indicate the high boron densities which can be achieved by this technique. The addition of aluminium, zirconium, tin and silver produced compacts which were of the same order of brittleness as untreated boron. The strongest compacts were formed by 10–15 wt.-% additions of nickel, manganese and copper; of these the nickel addition was chosen for further study on account of its nuclear feasibility.

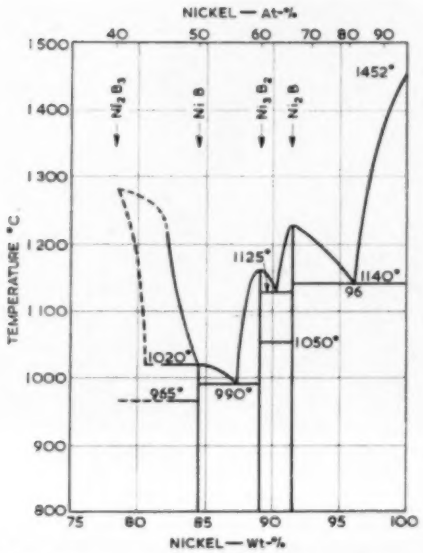


Fig. 5—The boron-nickel equilibrium diagram.

Fabrication of Boron-Nickel Mixtures

The B-Ni system (Fig. 5) has been studied by Giebelhausen.[6] It shows a four compound system, of which only the structures of Ni_2B and NiB have been established. The other phases are not isomorphous with any known boride. All the compounds have a melting point lower than that of pure nickel (1,445° C.), and the lowest eutectic system melts at 990° C. Thus, high boron mixtures, subject to moderate stress, could be expected to increase in density in two stages by a flow mechanism and by sintering.

The experimental procedure aimed at :—

(1) reaching as high a temperature as possible without complete melting or reaction with the container material ;

(2) maintaining the applied stress throughout the heating cycle to obtain initial densification by flow of material ; and

(3) maintaining the body at the highest possible temperature for a length of time necessary to obtain the desired density by sintering.

The five variables associated with the hot pressing stage, whose effects are reflected in the final bulk density, are :—

(*a*) type of boron nitride liner ;

(*b*) purity and physical form of the boron ;

(*c*) the temperature cycle ;

(*d*) the pressure cycle ; and

(*e*) the boron-nickel ratio.

These were examined in turn, keeping the other four variables as constant as possible. With the exception of (*b*) and (*e*) all experiments were performed on 10 wt.-% nickel-boron mixes.

TABLE II.—EFFECT ON THE BULK DENSITY OF 10 WT.-% NICKEL BORON COMPACTS USING VARIOUS BORON NITRIDE LINERS

No.	Type of Liner	No. of Compacts	Average Bulk Density (g./cc.)
1	Hot Pressed (U.S.A.)	2	2·80
2	Hot Pressed *in situ*.	4	2·30
3	Hydrostatically Cold Pressed.	2	2·50
4	Rammed.	33	2·45

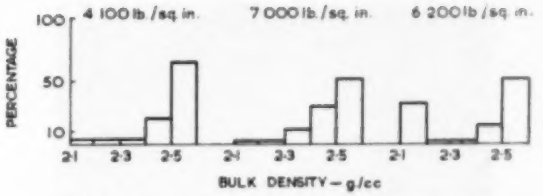


Fig. 6—The effect of pressure on bulk density.

(a) Type of Boron Nitride Liner

The effect on the final bulk density was investigated using four different types of boron nitride liner :—

(1) American hot pressed material ;

(2) material hot pressed *in situ* ;

(3) hydrostatically cold pressed material ; and

(4) rammed material.

The boron nitride powder of >99% purity used was obtained from the U.S.A.

The American boron nitride sleeves were made by hot pressing solid cylinders and machining out to the required wall thickness.

The boron nitride powder was hot pressed as a solid cylinder *in situ* inside the graphite die at 1,800° C. under a load of 2 tons/sq. in. The centre was machined out with a tungsten carbide tipped tool to leave a $\frac{1}{8}$ in. thick wall.

Hydrostatic pressing was performed inside the graphite die, by packing boron nitride powder round a length of neoprene tubing held axially through the graphite die. Rubber end seals were fitted inside the die cavity, and the whole die enclosed in a P.V.C. bag with the neoprene tubing protruding through. The die was then placed in an oil chamber and the lining subjected to a pressure of 15 tons/sq. in.

Ramming was done manually using a shaped ram around a central metal former.

The effect of the four types of liners on the bulk density of a number of compacts made under otherwise comparable conditions is given in Table II.

The superiority of the American material was evident from the bulk density figures, and the finish of the as-pressed compacts, which were within ±0·0005 in. on their 0·5 in. diameter. No machining was therefore necessary. The boron nitride liner was under considerable tension, and the boron compact could only be removed by slitting the liner. There was no adherence of boron nitride to the boron compact.

No detectable difference was found between the *in situ* hot pressed material and the hydrostatically pressed material. Both were inferior to the U.S.A. material

TABLE III.—COMPARISON OF COMPACTS MADE WITH BORON FROM VARIOUS SOURCES

No.	Source of Boron	Boron Purity (%)	Main Impurities (%)	Additions (wt.-%)	No. of Compacts	Average Bulk Density (g./cc.)
1	Natural B	89	—	—	2	2·30
2	Natural B (Borax Consolidated)	95	O_2 1·22 —	—	3	2·30
		—	Mg 0·70	—	—	—
3	Natural B	92	—	Ni 10	5	2·40
4	B[10]	92	Cu 0·6 Fe 1·6	Ni 10	22	2·40

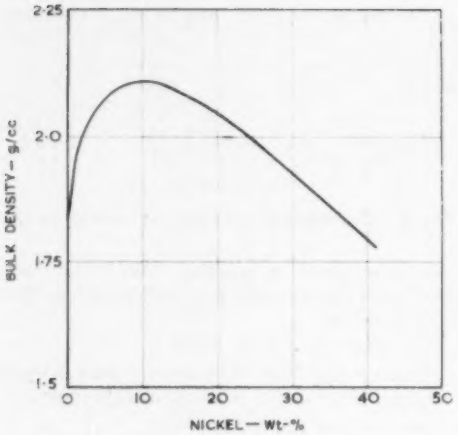


Fig. 7—Nickel concentration v. bulk density.

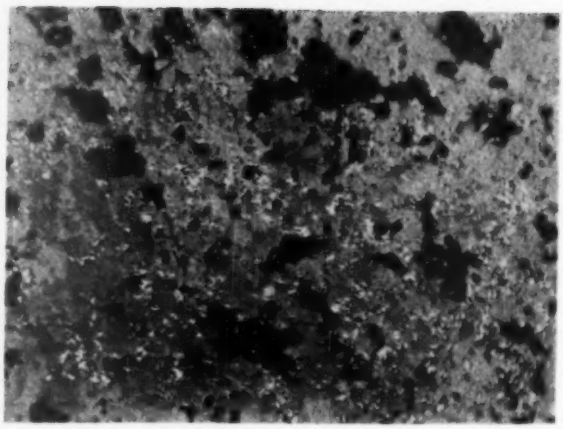


Fig. 8—Typical section of a boron-nickel alloy. × 250

regarding machinability. The slightly better densities of the compacts obtained from pressed liners do not justify the fabrication and machining necessary for their production. A pressed boron nitride end-cap was superior to a boron nitride powder coating in two ways: (*a*) a superior surface was obtained on the boron compacts thereby reducing the amount of machining necessary; and (*b*) it eliminated edge cracking, which necessitated a great deal of machining of the face to achieve the required overall diameter.

(*b*) *Boron from Different Sources.*

Compacts of natural boron of electrolytically produced material, and of isotopically separated B^{10} were comparable. (Table III).

(*c*) *Temperature Cycle.*

Initially the temperature was measured with an optical pyrometer which was sighted on a hole drilled into the die wall. This method proved unreliable due to the evolution of fumes into the sight tube, and attempts to eliminate fumes by using refractory sleeves were unsuccessful. A tungsten-molybdenum couple gave more consistent results. With both methods, slight differences of temperature between runs had a pronounced effect on the properties of the finished compact. In conjunction with the temperature indicator, a micrometer dial gauge, fixed between the press platen and a rigid pillar, was used to observe compaction rates.

(*d*) *Pressure Cycle.*

Hot pressing was carried out at <4,000, 4,100, 6,200, 7,000 and 8,200 lb./sq. in. Experiments at pressures greater than 7,000 lb./sq. in. were discontinued at an early stage, due to a high fracture incidence of the graphite plungers. Results obtained at the selected lower pressures viz: 7,000, 6,200 and 4,100 lb./sq. in. are shown by means of histograms in Fig. 6. Experiments conducted at pressures below 4,000 lb./sq. in. resulted in compacts of high porosity.

(*e*) *The Boron/Nickel Ratio.*

A series of 10 g. compacts in which the nickel addition was varied from 5 to 40% by weight, was hot pressed at 4,100 lb./sq. in. Temperature was increased uniformly for each compact until the dial gauge indicated that compaction had ceased. After density determination, the specimens were sectioned for metallographic examination. Fig. 7 illustrates the variation of bulk density with nickel concentration and shows a maximum density at 10% nickel.

On microscopic examination, all the nickel-bearing compacts show three phases which were not identified. The highly dispersed white phase, brought out by careful etching, increases with nickel concentration. A typical section is shown in Fig. 8.

Production of Natural Boron plus Nickel Compacts

Elemental boron was used to produce a series of boron-nickel compacts under optimised conditions of pressure, temperature, composition and time. The total weight of each compact was 15 g., which included 10% nickel by weight. A pressure of 4,100 lb./sq. in. was used throughout the operation, which took 16 ± 1 min. A maximum temperature of 1,950° C. was reached after 11 ± 1 min. and this was maintained for 5 min.

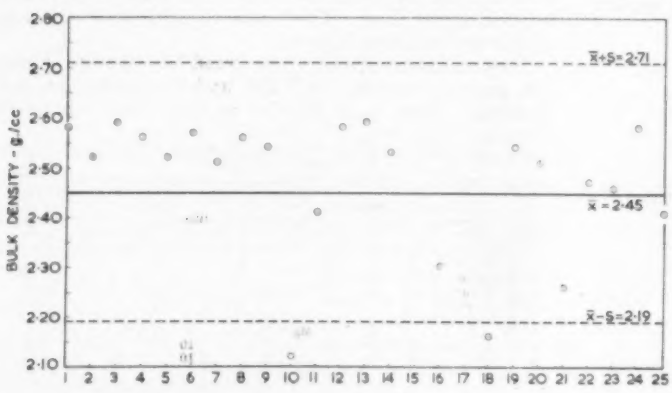


Fig. 9—Statistical presentation of bulk density determinations on alloys of natural boron + 10 wt.-% nickel.

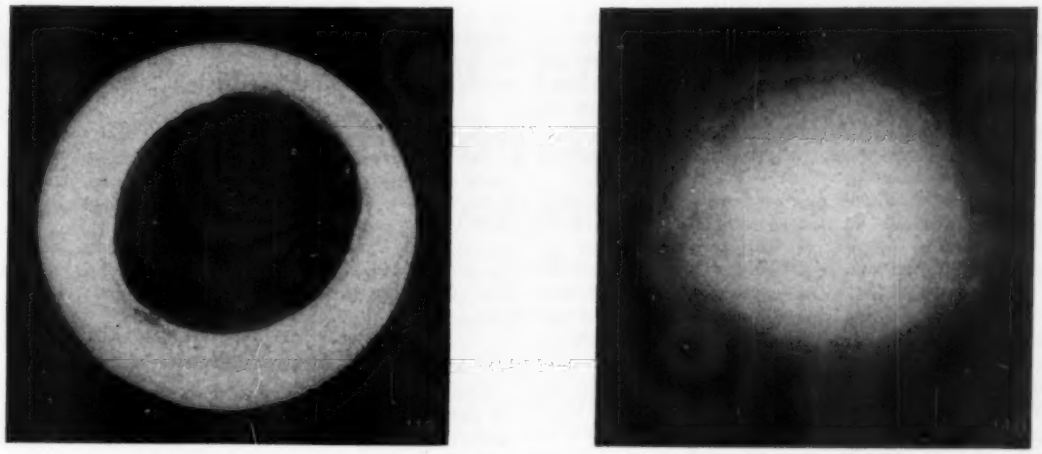


Fig. 10—Radiographs of boron-nickel compacts : 110—cored compact ; 140—sound compact.

Twenty-five compacts were made and the bulk densities determined, the results being given statistically in Fig. 9.

The mean bulk density ($\bar{x}$) of twenty-five compacts was 2·45 g./cc., which is equivalent to a boron concentration of 2·1 g./cc. The standard deviation (S) was 0·2645, and 68% of the compacts had a bulk density between $\bar{x}$ and $\bar{x} + S$. Taking $\bar{x} + S$ and $\bar{x} - S$ as the upper and lower limits respectively, then 8% of the compacts lie below the lower limit.

In the initial experiments designed to optimise the operation parameters, densities were determined before machining by the Archimedes method of water immersion. As the process developed and the machining of successful compacts was achieved, densities were found by directly measuring and weighing the machined compacts.

Inspection.

Defective compacts could be classified in three groups :—

(*a*) under-heated compacts which were characterised by a porous coke-like structure ;

(*b*) over-heated compacts vitrified with innumerable blowholes ; and

(*c*) specimens which appeared sound after pressing but which broke in a characteristic manner : these compacts consisted of a porous core and a dense outer shell.

Radiography offered a simple means of detecting a cored specimen, and a Newton Victor Raymax crystallographic unit was used. An exposure time of about 5 min. using Kodak Crystallex film, was suitable for $\frac{1}{4}$ in. thick compacts. Fig. 10 shows two radiographs, No. 110 is typical of a cored compact and No. 140 is an example of a sound compact with superficial crazing.

Machining.

Because of the extreme hardness of boron (Moh's scale 9-10) and the brittle nature of the compacts, conventional machining techniques were not considered. Three other machining methods were investigated, spark erosion, ultrasonic and diamond grinding. A tolerance limit of ± 0·002 in. was set for all surfaces.

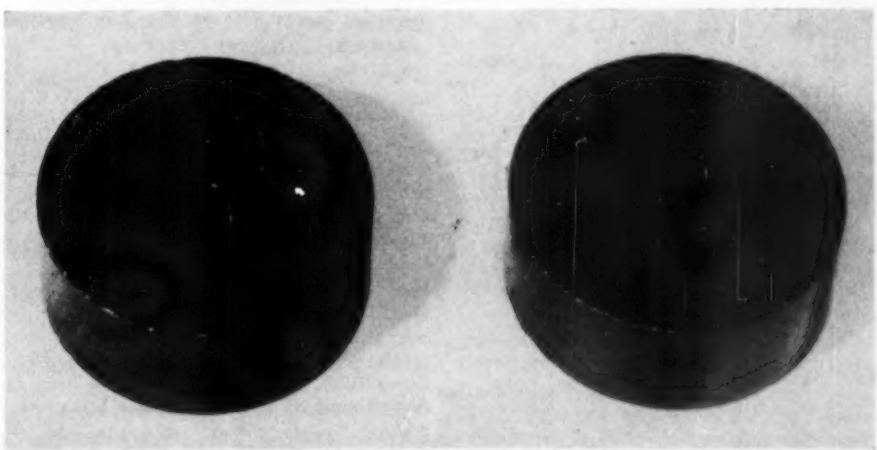


Fig. 11—Machined boron compacts. × 2 (approx.)

Spark erosion at a feed of 0·002 in./min. did not produce a surface finish within the required tolerance. Since this was the minimum feed rate which could be tolerated no further investigations were made. Furthermore, the cutting electrode eroded at a similar rate to that of the compact. Ultrasonic equipment, used at a similar feed rate, produced surface finishes well within the required tolerance.

Six compacts, variously mounted on rubber and cork matting, or "potted" in a thermoplastic resin and in "picein," were trepanned on the face, but they all shattered during the machining of the circumference when the same depth of cut was reached. This was probably due to a resonance effect set up within the brittle material. The abrasive was a boron carbide-water slurry pumped round via a settling tank.

Diamond grinding produced a finish well within the required tolerance, and over a hundred compacts were ground without a failure which could be attributed to grinding. For grinding the compact was held in a simple mild steel holder by wax, and one face was ground. The compact was reversed in the holder, the ground face located on a flat surface, reaffixed with wax and the other end ground. The outside diameter was finally ground between centres i.e. the compact was held between false centres made to suit the universal grinder. Adherence of the slug to the false centres was assisted by a thin film of adhesive. Grinding was done with a diamond impregnated wheel 8 in. diameter × ¼ in. wide at 1,675 r.p.m. using 0·0008 in. cuts. Some machined cylinders are shown in Fig. 11.

Conclusions

Boron rich alloys, containing about 10 wt.-% of metals such as nickel, manganese and copper, can be made and fabricated by a simple hot pressing technique. The bulk density of the compacts is ⩾2·0 g./cc., which is suitable for certain types of nuclear reactors. The extreme hardness of boron suggests that compacted boron-rich alloys may find some application in the abrasive or cutting tool industry.

Acknowledgments

The authors acknowledge with thanks the permission of Sir William Cook (Managing Director) and Dr. H. Kronberger (Director of Research), of the Development and Engineering Group, U.K.A.E.A. to publish this article.

REFERENCES

1 F. G. Stroke, A.E.C.D., 2291.
2 W. Wellborn, A.C.C.D., 2732.
3 Weintraub, *Trans. Am. Electrochem. Soc.*, 1909, **16**, 165.
4 Tiede and Birnbrauer, *Z. Anorg. Allgem. Chem.*, 1914, **87**, 129.
5 M. A. Rollier, Polytechnic School of Milan.
6 Giebelhausen, *Zeitschrift für anorganische und allgemeine Chemie*, **91**, 1915, 250.

Personal News

TUBE INVESTMENTS, LTD., announces that MR. C. H. T. WILLIAMS, J.P., and MR. E. G. PLUCKNETT have been appointed to the board. Mr. Williams is chairman of Park Gate Iron & Steel Co., Ltd., and Round Oak Steel Works, Ltd., and Mr. Plucknett is managing director of Simplex Electric Co., Ltd.

MR. V. C. FAULKNER has retired from the editorship of *Foundry Trade Journal*, after occupying the position for nearly forty years, but retains his connection with the journal as editorial director. He is a past-president and an Oliver Stubbs medallist of the Institute of British Foundrymen, and a past-president of the International Committee of Foundry Technical Associations. Mr. Faulkner is succeeded by MR. A. R. PARKES, a member of the general council of the I.B.F., and senior vice-president and secretary of the London branch, who has been assistant editor for the past thirteen years.

MR. J. F. STANNERS has succeeded DR. J. C. HUDSON, who has retired as head of corrosion research in the chemistry department of B.I.S.R.A. From 1940 until 1945, Mr. Stanners was engaged on the measurement of radio-activity at what is now the Radiochemical Centre at Amersham. He then joined the staff of the corrosion committee of the Iron and Steel Institute, transferring to B.I.S.R.A., with Dr. Hudson, when this committee was taken over by the Association. MR. E. E. WHITE, has been appointed head of the B.I.S.R.A. corrosion advice bureau. He joined B.I.S.R.A. in 1950 as the technical secretary of the corrosion committee and chemistry department, and in 1954 was additionally appointed secretary of the newly formed corrosion advice bureau.

THE RT. HON. THE VISCOUNT HEAD OF THROOPE, P.C., C.B.E., M.C., has resigned from the board of Associated Electrical Industries, Ltd., as a result of his appointment as the first High Commissioner in the Federation of Nigeria. SIR JOSEPH LATHAM, C.B.E., formerly deputy chairman of the National Coal Board, has been elected a director, and MR. C. R. WHEELER, C.B.E., has been appointed an additional vice-chairman: Mr. Wheeler will take up executive duties in 1962.

THOMAS MARSHALL & CO. (LOXLEY), LTD., fireclay refractory manufacturers of Sheffield, announce the appointment of two assistant managing directors. MR. W. T. HALE, sales director becomes assistant managing director on sales and commercial matters, and MR. T. A. MARSHALL, director responsible for production, takes up the appointment of assistant managing director generally responsible for production and works' control.

THE International Meehanite Metal Co. Ltd., announce a reorganisation in their board of directors, in which MR. O. SMALLEY, O.B.E., becomes chairman and MR. P. ATTENBOROUGH managing director. The remaining directors are MR. E. M. CURRIE, MR. E. W. HARDING and MR. G. HOBMAN.

WEST INSTRUMENT, LTD., the temperature control instrument manufacturers, now have a full-time representative in France. He is M. Dé MICHEL who will be responsible for the company's wide activities in the field of temperature recording, indicating and controlling in the plastics, metallurgical, nuclear and other fields and his appointment is a step in co-ordination of the substantial business now being done by West Instrument throughout Europe.

MR. E. H. S. VAN SOMEREN has recently joined the British Welding Research Association as a principal scientific officer and is to work on fundamental studies on the physics of the welding arc by optical observations. Since 1958 Mr. van Someren has been in the research department of Murex Welding Processes, Ltd.

UNION CARBIDE, LTD., announce the appointment of MR. W. B. WHITWORTH as sales manager of the alloys division.

The Protection of Iron and Steel by Aluminium Coatings

By D. R. Andrews*, A.I.M.

The various processes available for the coating of iron and steel by aluminium are discussed with special reference to metal spraying and hot-dip aluminising, and to calorising, which is mainly used where resistance to scaling at high temperatures is required. Besides a brief description of the process, an indication is given of the structure and properties of each type of coating.

WHEN one is faced with the problem of providing a protective coating on iron or steel, there appear to be so many different ways in which it can be done that it is difficult to assess their relative merits. The purpose of coating iron or steel with aluminium is the production of a surface resistant to corrosive action, whether of the normal or high temperature type. Study of the relative electrochemical characteristics shows that it is reasonable to assume that the aluminium coating would be anodic to the basis material, and would therefore afford sacrificial protection under wet corrosive conditions. It is necessary, however, to take the environment into consideration, since the film of aluminium oxide in many cases renders the coating cathodic. Should this film be broken down, the coating will be found to be anodic.

Under accelerated testing conditions, it is only possible to obtain a guide to the likely behaviour under service conditions, actual field trials are necessary before an accurate assessment can be made. Unfortunately, in the case of corrosion, such trials take a long time, and it may be years before really sound conclusions can be drawn from them. Nevertheless, the possibility of using aluminium as a protective coating on iron and steel has been recognised for so long that comparisons between aluminium and zinc coatings are possible.

The life of a protective coating is greatly dependent on its thickness where the coating is anodic to steel, and this factor must always be taken into consideration in assessing the results of tests. These show that, for the same coating thickness, the life of a sprayed aluminium coating is generally longer than that of a zinc coating under industrial conditions. Similarly, with hot-dipped coatings, aluminium has been found to be more resistant than zinc to conditions of high humidity or sulphurous atmospheres. Atmospheric exposure tests carried out by the A.S.T.M.[1] (Report of Sub-Committee VIII on Field Tests of Metallic Coatings) demonstrated the value of such coatings. In many cases, even though the hot-dip galvanised coating was thicker, the aluminised coating proved to be superior. Aluminium coated steel has shown a high resistance to sea coast conditions, but there appears to be conclusive evidence that as far as sea water immersion is concerned, zinc is superior to other metals, aluminium taking second place.

Metal Spraying

Iron and steel can be coated with aluminium or its alloys by metal spraying, hot dipping, cladding, casting-on, electroplating and heating in aluminium powder. Not all of these processes are widely used in this country —only spraying, dipping and heating in powder are operated to any extent. This may be due to the fact that in certain instances techniques have not yet been fully developed, and considerable research work still remains to be done. Electroplating of steel with aluminium is a good example of a process where many difficulties still exist. Generally speaking, the choice of process depends on economic considerations and on the service for which the product is intended, that is, whether the main object is corrosion resistance or resistance to scaling at high temperatures.

In the coating of iron and steel by metal spraying, use is made of a molten-metal, wire, or powder pistol, the sprayed metal being applied to a thoroughly cleaned, scale-free surface. For large structures, especially those in the open, flame descaling is particularly recommended, although the cost is considerably greater than for wire brush preparation.

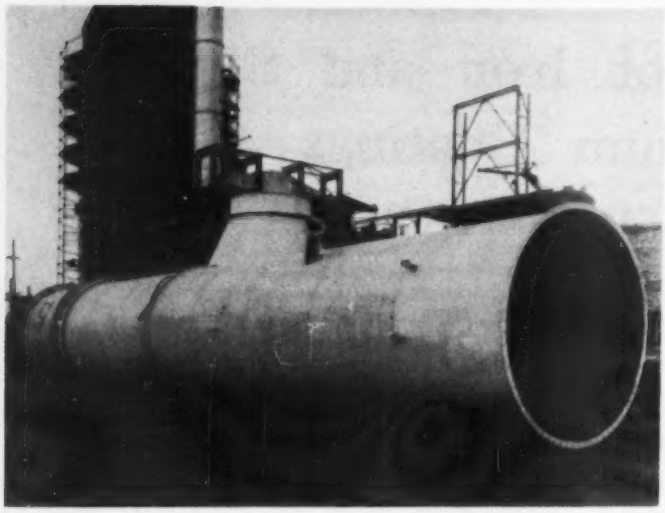
The molten-metal pistol is suitable for spraying fusible alloys, especially as such metals cannot readily be drawn into wire, nor are they easily obtained in powder form but the process is not recommended for aluminium. For one reason, molten aluminium readily oxidises in air, and trouble is experienced as a result of blocking of the nozzle by particles of aluminium oxide. There are also other difficulties.

Aluminium is usually sprayed by means of a wire pistol, where a flame of burning gas is used to melt the wire to be sprayed, and this flame is surrounded by a core of compressed air which disintegrates the film of molten metal as it forms, the small globules being blown forward at high speed. Considerable development work has been, and is being, carried out with a view to improving the design and efficiency of such pistols, particular attention being paid to nozzle design and the wire feed mechanism. The pistols can be operated manually or automatically: in the latter case a multiplicity of nozzles can be arranged in rows or in angle formation. Each is fed with an individual wire, the wires being presented to the nozzles by means of electrically driven feeds.

For the powder pistol four feeds are required. They are combustible gas, air, oxygen, and powder of a suitable particle size suspended in air. One of the chief advantages claimed for the powder pistol is that it contains no moving parts.

There are no limitations on component or structure

*Department of Metallurgy, College of Advanced Technology, Birmingham.



(*Courtesy of Metallisation, Ltd.*)

Aluminium-sprayed steel stack

size where spraying is concerned, as the process can be carried out on any size or shape of structure, and it has the advantage that recesses, corners, joints and similar areas where corrosion might commence can be given extra thick coats for added protection. Moreover, transport of the equipment to the structure presents no difficulties.

Sprayed aluminium coatings consist of metal particles surrounded by thin oxide films and some porosity. The metal particles are very small and are meshed together quite tightly, adhesion being purely mechanical, there being no alloy bond as is found with hot dip coatings. Examination of the microstructure shows that the metallographic structure is quite different from that of cast, wrought, hot dipped or plated metals. If the microsection is not carefully prepared and etched, it may appear that the deposit is several mils away from the base metal. This, of course, is not the case : correct preparation will reveal a fine line marking the boundary between base metal and deposit. Should the coating be too thick, flaking or peeling may occur under certain conditions.

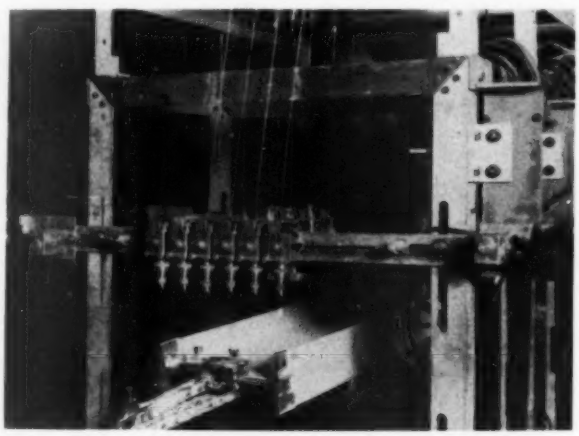
Despite the pores, a sprayed coating will protect iron and steel electrochemically, but a sealer can be applied if desired. The corrosion products when aluminium is present are extremely insoluble, and the pores become filled with these substances, thus stifling further action. The thickness of coating used is generally 3–5 mils and a layer of this thickness will soon possess an oxide film, giving increased protection and an excellent basis for paint. The painting operation should be carried out as soon as possible after spraying. If painting is not considered necessary, the matt finish of the sprayed coating will be found to be quite attractive in appearance.

Very large structures can be sprayed with complete satisfaction and maintenance costs reduced to a minimum, particularly when a correct painting procedure is also used. In nearly every investigation into the early failure of a sprayed coating, extraneous causes have been shown to be responsible : for example, unsatisfactory preparatory grit blasting may cause early rusting.

Where a structure is to be welded on site, the whole surface may be metal sprayed as a final operation or, alternatively, the component parts may be treated at the factory—possibly using mechanised spraying techniques—leaving unmetallised areas of sufficient width to allow satisfactory welding, the welded zones being themselves sprayed after erection. The latter procedure assists in the correct preparation of the surface, an operation more difficult to carry out in the field than in the factory, where conditions can be more closely controlled. It has been found possible to weld through thin aluminium coatings using special rods, but generally it is preferable to leave unmetallised sections within 2 in. of welding. Ballard[2] has examined the cost position, as far as the protection of structural steel is concerned, and found that the cheapest way of spraying constructional work is to treat as much as possible in the original sections or plate form in a mechanised plant, finishing off welds and joints on site by means of portable equipment.

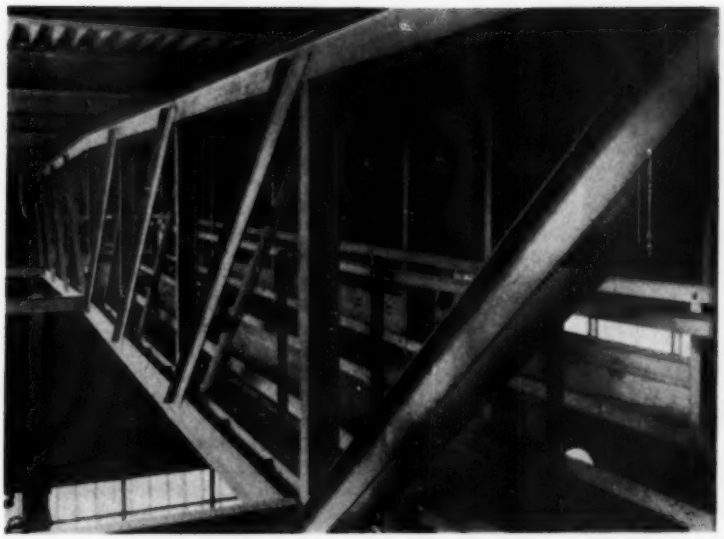
Mention may now be made of a method of protection against corrosion from gases in the temperature range 500°–950° C. Below 500° C. the natural oxide film provides a considerable measure of protection ; above 950° C. the process to be described is not effective. The process, which aims at the prevention of loose scale formation and the inhibition of oxidation of the underlying metal, is known as " aluminising " and must not be confused with " hot dip aluminising " : it is surprising how often in technical discussion this confusion does arise.

The article is first sprayed with aluminium—0·007–0·010 in. thickness is recommended—and then placed in a furnace already heated to 850°–950° C., where it should remain long enough for the surface to be thoroughly heated to this temperature. Before placing the component in the furnace, it should be coated with a layer of bituminous paint which will burn off during the heating and prevent undue oxidation of the aluminium



(*Courtesy of Coated Metals, Ltd.*

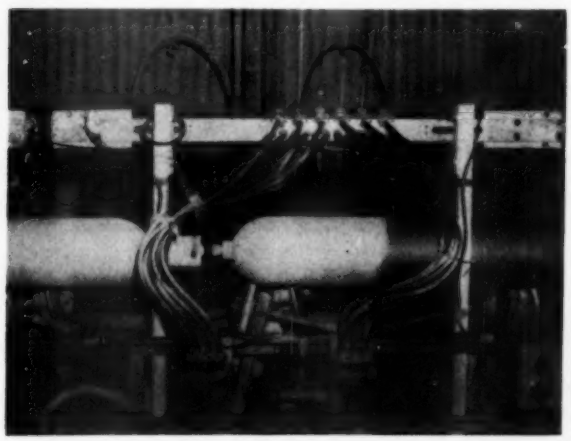
Mechanised spraying of joists



(Courtesy of Metallisation, Ltd.)

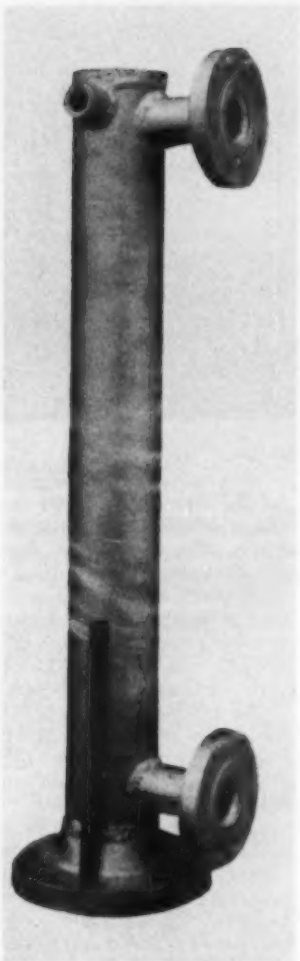
Aluminium sprayed structural steelwork nine years after erection

before alloying has taken place. If the use of bitumen is undesirable, other techniques are possible, such as coating with sodium silicate or spraying with an aluminium-cadmium alloy—in practice the wire contains 0·5–0·75% cadmium. It is not suggested that in all circumstances such treatment will provide adequate protection; service requirements should, therefore, be carefully studied or expert advice sought. Nor is it correct to assume that a sprayed component put straight into service at elevated temperatures will alloy properly, because in most cases heavy oxidation of the aluminium will occur before formation of the iron-aluminium compounds. A large number of steels can be successfully aluminised, but it should be noted that oxide inclusions near the surface of the base metal will interfere with diffusion, and roaks, laminations and similar defects frequently cause early failure of coatings.



(Courtesy of Metallisation, Ltd.)

Mechanised spraying of steel gas cylinders



(Courtesy of Coated Metals, Ltd.)

Hot dip aluminised flanged pipe assembly

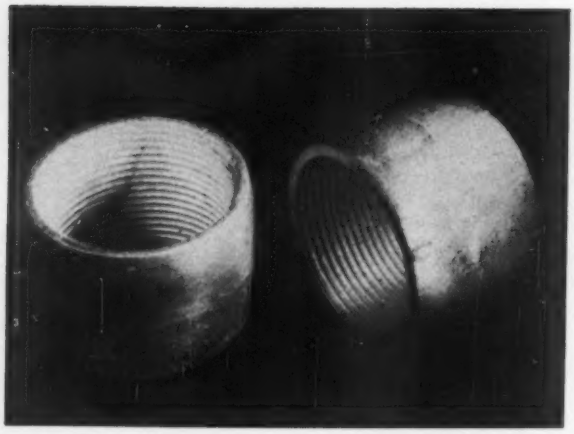
Alloy steels can also be treated in this manner, but they aluminise much more slowly. Where a high percentage of chromium is present, the tough chromium oxide film on the steel surface probably offers considerable resistance. As far as cast iron is concerned, it should be low in silicon and the amount of free graphite should be small.

The size of component which can be treated is limited only by the dimensions of the furnace available for the final treatment.

Hot Dip Aluminising

This is a process very similar in many respects to hot dip galvanising, and for the commercial coating of sheet, strip, wire or fabricated components, seems to have many advantages over other techniques. From an operating viewpoint, it seems to be the lowest in cost rating, especially if throughput is heavy. The development of a successful process of hot dipping has not been an easy task, however. Essential requirements are the careful pretreatment of the ferrous material, prevention of formation of heavy oxide films on the molten bath surface, and some method of treatment to protect the steel surface immediately prior to immersion.

There are numerous descriptions[3] and patents cover-



(Courtesy of Coated Metals, Ltd.)

Two hot dip aluminised pipe fittings

ing the process, in both batch and continuous forms. These details cover such items as the use of various fluxes, thin coatings of metals like zinc and tin, and reducing atmospheres. One method of treatment being successfully used in this country at the present time consists of degreasing and pickling followed by filming the steel with copper and/or a solution of glycol and isopropyl alcohol. The steel is then immersed in an aluminium bath containing a small addition of silicon.

The reason for the addition of silicon is explained in the papers of Gittings, Rowland and Mack,[4] Stroup and Purdy[5] and many other workers. The microstructure of a hot dip coating reveals the presence of an interfacial layer of iron-aluminium compound, which usually appears as a series of loops, not as an even layer such as results from diffusion into copper; such loops indicate that there has been preferential diffusion at certain points along the steel surface. The alloy layer is formed between the relatively pure aluminium on the surface and the base metal and research has shown the effect that alloying elements have on its thickness, the three most effective possible additions being copper, silicon and beryllium. As will be seen from Table I, beryllium produced the greatest decrease in thickness, 0·5% reducing the alloy layer approximately 77%: additions up to some 2% showed only a further slight decrease. Copper additions had to be considerable to have a similar result, but 2% silicon was very effective and appears to be the most suitable choice, as beryllium raises difficulties from a health point of view and copper has been found to affect coating adherence, apart from the objection which might be raised to the large addition required.

Alloy layer thickness is very important, for in many instances a coating must be able to withstand considerable deformation, and like many interfacial alloys this layer is extremely brittle. The silicon addition, however, reduces the thickness and hardness and, therefore, bending and forming may be carried out without risk of coating failure.

Bath temperature is also important for, as the temperature increases, so the interfacial layer increases in thickness, whether the iron or steel component is immersed in a pure aluminium or alloy bath. A much wider temperature range can be tolerated when a silicon addition is employed, but modern plants are fully instrumentated to obtain the best possible type of coating for corrosion resistance. Where heating of the coated component is contemplated for any reason whatsoever, the effect on the alloy layer must be carefully considered. Tests carried out on tensile and bend specimens, aluminised and then heat treated, showed considerable decrease in mechanical properties, unless the time and temperature were very carefully controlled, due to growth of the alloy layer.

For resistance to scaling only, a coating consisting of the iron-aluminium compound may be employed, as this coating has useful heat resisting properties. Annealing of a hot dipped component to obtain such properties would be expected to be more successful than annealing a sprayed coating, as diffusion can be more uniform across the interface where there is a more continuous contact.

It is more difficult to aluminise cast iron than steel by hot dipping. If the surface layer of the cast iron is heavily decarburised then the adherence of the aluminium will be found to be improved. Very little information exists on the subject, and there would appear to be only slight interest industrially.

In many respects, hot dip aluminised coatings are comparable with sprayed and heat treated coatings. The main distinction lies in appearance and thickness, the dipped coatings in general being thinner and brighter: their protective ability is very similar. It is possible to anodise aluminised steel. The Bethlehem Steel Company[7] has developed a hot dipping line to deal with small fixtures and fittings such as ¼-in. diameter bolts. The articles are first degreased and pickled in 8–10% sulphuric acid, then some 50 lb. of hardware is loaded into a steel mesh basket 12 in. in diameter and 15 in. high. Six such baskets at a time can be placed in a preheating and fluxing salt bath furnace heated to about 1,300° F. (705° C.) by five pairs of electrodes. Working space is 18×94×40 in. After some 8–15 minutes in this salt bath the basket is rapidly transferred to the aluminium coating furnace, which is an induction unit of 35 kW. capacity, the working space being 24×24×42 in. The basket is moved up and down several times while in the furnace. A coating thickness of about 0·0025 in. is usual, immersion time being in the region of 1–3 minutes.

The basket containing the small coated articles is then rapidly positioned in a centrifuge, the speed of which depends on the articles. Large unthreaded parts are spun at slow speeds and small threaded bolts at higher speeds. Spinning time varies from 15–60 seconds and cold water quenching follows. This is an interesting process and it is reported that excellent, uniform coatings are thus produced, giving extremely satisfactory resistance to atmospheric corrosion over a very long period.

TABLE I.—EFFECT OF BERYLLIUM, COPPER AND SILICON ON THICKNESS AND MICROHARDNESS[6]

Alloying Element	Concentration (%)	Decrease in Average Thickness of Alloy Layer (%)	Average Microhardness (K.H.N.)
Beryllium	0·05	35	807
	0·1	50	996
	0·2	71	770
	0·5	77	518
	0·8	80	482
	1·0	76	560
Copper	1·8	25	672
	6·4	34	807
	15·4	50	807
	27·2	66	859
Silicon	0·75	42	792
	1·5	58	792
	2·25	68	742
	3·0	69	661
	6·0	75	340

In the United States, wire products are now commercially available and new producers seem to be entering the field with increasing frequency. It is reported[8] that aluminised wire is readily redrawn, since the coating operation anneals the steel. Redrawing, which is necessary to obtain high strength, results in improved lustre and surface texture. Bath temperature, speed of coating and cooling rate of the wire all require close control, for the best characteristics of aluminised wire are obtained only when the requirements for good coating are fully met. As with sheet and strip, these requirements at the present stage of development call for closer technical control than generally encountered in galvanising.

The corrosion resistance, mechanical strength, formability and cheapness of aluminised sheet, strip and wire will, no doubt, lead to increased use in the future. In the canning industry, for example, aluminised steel will be a serious competitor for tinplate if can manufacturing technique is altered so that soldering can be avoided. Again, there would seem to be a wide range of pressed and formed articles where aluminised steel, probably anodised and dyed, would have considerable advantages.

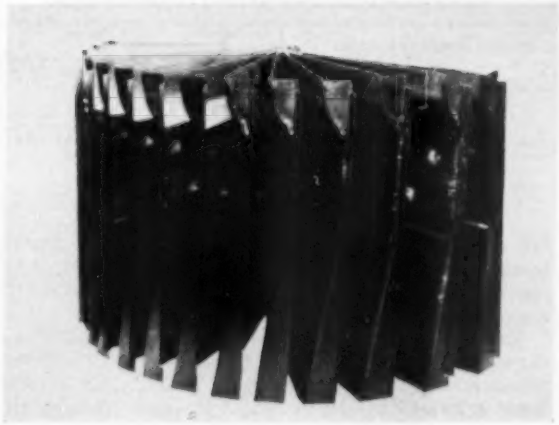
Cladding

The idea of roll-bonded aluminium coatings on steel is not new, but it is believed that no one is manufacturing this type of clad material in Great Britain at the present time. There is, therefore, little scope for comment at this stage. Cladding processes based on sealed-assembly rolling are being carried out to a certain extent in Germany. In one process, a roughened steel strip surface is sandwiched between two aluminium strips by an uncoiling, rolling, recoiling technique at a temperature which results from the rolling process itself: an annealing treatment follows. Workers have found that annealing frequently results in a doubling of strength in such a bonded material. A possible development for the future is cladding as an extrusion operation. Preliminary experimental work in the United States has shown that such a technique may well be possible.

Casting Aluminium around Steel

This process consists of the casting of aluminium or its alloys around a steel component, the surface of the ferrous metal having previously been prepared by precoating; there are a number of modifications of the technique. The advantage of the process is that the structural strength of the steel is combined with the excellent thermal conductivity and high-temperature corrosion resistance of the aluminium. Such a combination of properties has naturally led to considerable use of the technique in the aero-engine field, particularly in the States. The ductile light alloy expands and contracts along with the stiffer ferrous metal, but the bond has sufficient strength to keep the dissimilar metals together. Tensile, fatigue and actual service tests have proved that such a bond is satisfactory and, as an example, the general performance of cylinder barrels[9] manufactured in this manner has been much superior to steel barrels, because of the higher thermal conductivity of aluminium fins compared with steel.

Naturally, close technical control is necessary to restrict the thickness of alloy layer as considerable brittleness will result, but this difficulty can be overcome as it has been with hot dip aluminising. Originally the casting method was used to produce rather massive sections of aluminium or alloy around a steel core, as it was not originated for the production of thin coatings, but development work has now succeeded in making this possible.



(Courtesy of Coated Metals, Ltd.)

Aluminised panels for gas heater assembly

Electroplating

This method of coating steel with aluminium has been very limited in application. There appear to be many difficulties in selecting and operating available electrolytes. It is possible to plate satisfactorily on a laboratory scale but not on any production basis. It is necessary to use pure chemicals and high purity aluminium as an anode, and fuming of volatile aluminium chloride must be controlled.

Collins[10] has shown that an electrolyte of 80% aluminium chloride and 20% sodium chloride, operating at a temperature of approximately 175° C., will produce a smooth, matt type of deposit, with a current density in the region of 15 A./sq. ft. Below this figure adherence is unsatisfactory. The deposit is built up rather slowly, and throwing power is poor. There is no alloy layer formed unless some form of heat treatment is carried out after plating, or unless the component is subjected to temperatures of about 480° C. or above, in service.

Organic electrolytes containing compounds such as aluminium bromide in ethyl bromide and benzol, may be used.

Calorising

This was one of the earliest processes used for coating ferrous components with aluminium. It is frequently referred to in Great Britain and America as "calorising" and in Germany as "atilising." Although the technique has been varied considerably in general practice, it involves a preliminary descaling operation followed by sealing the components in air-tight containers partially filled with a powder containing metallic aluminium, alumina and small percentages of ammonium chloride, zinc and graphite. The alumina addition prevents the aluminium grains fusing together. The tightly sealed boxes or rotating drums are heated for several hours at a temperature of approximately 900° C. A layer several mils thick is thus provided, but of such a high aluminium content that brittleness will be much greater than can be tolerated. Hence a further heat treatment in the absence of aluminium is necessary, and for this purpose

TABLE II.—SCALING RESISTANCE OF CALORISED STEEL

Nominal Composition of Steel (%)				Increase in Weight, (mg./sq. cm.) after 1,000 hr. at			
				595° C.		650° C.	
C	Mn	Cr	Others	Uncoated	Calorised	Uncoated	Calorised
0·06–0·20		18·0	8·0 Ni			1·1	0·6
0·08–0·18	0·3–0·6	5·0	1·0 W			17·5	1·0
0·08–0·18	0·3–0·6		1·5 Mo	35·4	1·3		
0·08–0·18	0·3–0·6	1·25	0·5 Mo	19·9	1·5		
0·08–0·18	0·3–0·6		0·5 Si	41·0	4·3		

the components are removed from the retort. Such a treatment will improve ductility and toughness of the coating as it will permit further diffusion and reduce the aluminium content of the surface.

The microstructure of a typical calorised mild steel shows an outer layer of alumina, a region of iron-aluminium phase and the base metal. The alumina layer is formed by the oxidation of the aluminium rich surface and this zone will reduce further oxidation. Calorised steel and cast-iron components can be satisfactorily used at elevated temperatures up to approximately 925° C. The excellent scaling resistance of calorised steel is shown in Table II. Resistance to sulphurous gases is also pronounced and the treatment offers a valuable alternative to the use of alloys which are particularly vulnerable to sulphurous fumes.

Fabrication of calorised iron and steel is not practicable even if carried out at a high temperature so that its use is restricted to such parts as conveyor chains, frames of heat treatment furnaces, baffle plates, parts in ore treatment furnaces like the Wedge roaster, heat exchanger components, etc., where full advantage can be taken of its resistance to elevated temperatures and sulphurous gases.

TABLE III.—RESISTANCE OF CALORISED STEEL TO A HYDROGEN SULPHIDE ATMOSPHERE[11]— 24 hrs. at 650° C.

Nominal Composition of Steel (%)				Increase in Weight (mg./sq. cm.)	
C	Mn	Cr	Others	Uncoated	Coated
0·08–0·18		18	8·0 Ni	36·5	0·1
0·08–0·18	0·3–0·6	5	1·0 W	175·6	0·5
0·08–0·18	0·3–0·6	5	0·5 Mo	172·8	1·3
0·08–0·18	0·3–0·6	2	0·5 Mo	124·3	0·5
0·08–0·18	0·3–0·6		0·5 Si	173·5	0·6

Acknowledgment

Acknowledgment is made to Metallisation, Ltd., and Coated Metals, Ltd., for their kindness in providing photographs for reproduction:

REFERENCES

1 *Proc. A.S.T.M.*, 1944, **44**, 92–109.
2 Ballard, W. E., *Chem. and Ind.*, 1955, 1606–1611.
3 Hughes, M. L., and Moses, D. P., *Metallurgia*, 1953, **48**, 105–122.
4 Gittings, D. O., Rowland, D. H., and Mack, J. O., *Trans. A.S.M.*, 1951, **43**, 587–610.
5 Stroup, P. T., and Purdy, G. A., *Metal Progress*, 1950, **57**, 59–63, 128, 130.
6 Gittings *et al.*, *loc. cit.*
7 *Steel*, 1957, **140**, (5), 105–106.
8 Sprowl, *Wire and Wire Prod.*, 1956, Oct. 31 (10) 1160–1163; 1273–1277.
9 Whitfield, M. G., and Sheshunoff, V., *Materials and Methods*, 1945, **22**, 1090–1096.
10 Collins, F. R., *Iron Age*, 1952, Jan. 17th, **169**, 100–101.
11 Sayles, R. J., "Metals Handbook," A.S.M., 1948, 703–704.

News in Brief

ORDERS have been received by Film Cooling Towers, Ltd., of Richmond, Surrey, for natural draught water cooling towers to be erected at Richborough power station, Kent, and the new Spencer Works of Richard Thomas and Baldwins, Ltd., near Newport. The latter towers are to serve the power station and blast furnace and gas cleaning plants. Two multi-cell induced draught water cooling towers are to be erected at the same works for the oxygen plant.

A NEW Scottish sales and service centre of the Griffin & George group was opened recently at Braeview Place, Nerston, East Kilbride, Glasgow.

THE gas atmospheres division of the Incandescent Heat Co., Ltd., has recently received a contract worth approximately £55,000 for equipment to be installed in a large Belgian steelworks. It is for three gas generators, each capable of producing 10,000 s.c.f.h. of a nitrogen/hydrogen mixture, and will bring the number of Incandescent nitrogen generators operating overseas up to nineteen—nearly 30% of the total production.

DOUBLE volute horizontal single-stage centrifugal pumps are to be made by the David Brown Foundries Division to the designs of The Bingham Pump Co., of Portland, Oregon, U.S.A., and marketed in the whole of the eastern hemisphere, with the exception of Australia, New Zealand, and part of Japan.

Two contracts totalling £362,000, have been placed with The General Electric Co., Ltd., by Richard Thomas & Baldwins, Ltd., for the new Spencer Works at Llanwern, near Newport, Monmouthshire. One covers nine 1,500 kW., 460 V., steel-tank mercury-arc rectifiers with associated transformers and earth-leakage and regenerative control panels. These rectifiers will be sited at strategic points in the plant to provide power for cranes and mill auxiliaries. The other is for the complete electrical equipment for a 62-in. wide continuous pickle line.

WITH rapidly growing sales to Northern Ireland, Albright and Wilson (Mfg.) Ltd., has opened a sales office at Imperial Buildings, 72, High Street, Belfast (telephone No: Belfast 32312; telegraphic address: Albriwil-Belfast).

WILD-BARFIELD ELECTRIC FURNACES, LTD., have nearly fifty furnaces on order for India, varying from small laboratory muffles to production units. Included in export orders to Belgium is one for a Wild-Barfield/NRC Model 2801 C crystal pulling furnace, while an order has been received for a large high temperature furnace destined for the Royal New Zealand Air Force. Laboratory and toolroom equipment is also being manufactured for Canada by Wild-Barfield.

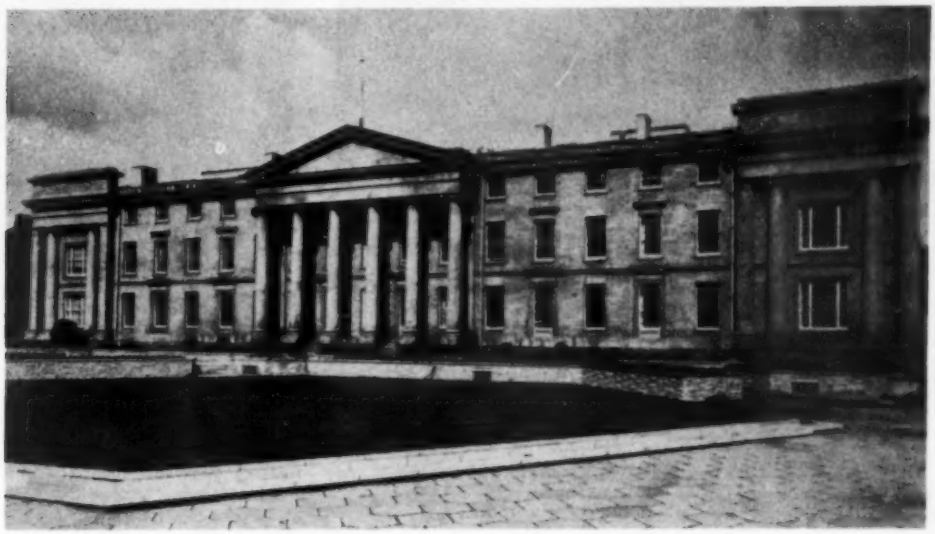
ALUMINIUM, LTD., has established two new fabricating plants, one in Jamaica and one in Trinidad, to produce corrugated aluminium sheet and ancillary rain water goods for the local markets. The two factories together have an annual corrugated sheet capacity of about 3,000 tons: they will both use Alcan aluminium.

WALKER, CROSSWELLER AND CO., LTD., of Cheltenham, have opened a new office block in the town. This houses their sales and service departments, which retain the old telephone number (Cheltenham 56317) and address. Departments at the factory (accounts, works offices, buying and publicity) have a new number: Cheltenham 56366.

To accommodate the increase of staff due to rapid expansion, Union Carbide, Ltd., moved their head office to Union Carbide House, 8, Grafton Street, London, W.1. The headquarters of the chemicals, alloys, polyethylene and kemet divisions will also be in this building.

United Steel's New Headquarters

Transformation of Century-Old Building



Only minor alterations have been made to the front elevation of The Mount, which was built in 1834. The bowling green in the foreground is on the roof of the car park.

THE head office of The United Steel Cos., Ltd., previously situated in a number of converted private houses in Westbourne Road, Sheffield, was transferred to new headquarters at The Mount, Broomhill, during January of this year. Here, about a hundred yards from the old premises, there is accommodation for a staff of approximately 150 people, some of whom are housed in The Mount itself, a 126-year-old building which has undergone intensive internal reconstruction, while others are accommodated in an entirely new four-storey block and interconnecting wing which have been built behind the main building.

Underground car park for some 60 cars: a staircase leads to the main building and lifts to other floors.

Designed by William Flockton, a well-known Sheffield architect, The Mount was built in 1834 as a block of eight private houses sharing a common pillared facade in the classical style. One of the first occupants was James Montgomery, the hymn writer, journalist and sociologist, who helped to found most of the organisations for intellectual, moral and social improvement which existed in the town at the time of his death in 1854. John Holland was another local literary celebrity who lived at The Mount: a friend of Montgomery, he followed him as editor of the *Iris* weekly newspaper. Industrialists, headmasters, ministers and stationmasters were among those who lived at The Mount at various times. Subsequently, it was acquired by John Walsh, Ltd., who used it as their business premises after the 1940 blitz had destroyed their large department store. When the new store building was completed a few years ago, Walsh's sold The Mount to United Steel, and work began on the conversion and addition to the premises in May, 1958. The architects were J. Mansell Jenkinson & Sons, and the main contractors, Geo. Longden & Son, Ltd.

In general, it has been the intention of the architects to maintain the original character of the building, and the front façade was retained in its original form, whilst almost the whole of the internal structure was removed. Steel framework was introduced to strengthen the build-

TABLE II.—SCALING RESISTANCE OF CALORISED STEEL

Nominal Composition of Steel (%)				Increase in Weight, (mg./sq. cm.) after 1,000 hr. at			
				595° C.		650° C.	
C	Mn	Cr	Others	Uncoated	Calorised	Uncoated	Calorised
0·08–0·20		18·0	8·0 Ni			1·1	0·6
0·08–0·18	0·3–0·6	5·0	1·0 W			17·5	1·0
0·08–0·18	0·3–0·6		1·5 Mo	35·4	1·3		
0·08–0·18	0·3–0·6	1·25	0·5 Mo	19·9	1·5		
0·08–0·18	0·3–0·6		0·5 Si	41·0	4·3		

TABLE III.—RESISTANCE OF CALORISED STEEL TO A HYDROGEN SULPHIDE ATMOSPHERE[11]— 24 hrs. at 650° C.

Nominal Composition of Steel (%)				Increase in Weight (mg./sq. cm.)	
C	Mn	Cr	Others	Uncoated	Coated
0·08–0·18		18	8·0 Ni	36·5	0·1
0·08–0·18	0·3–0·6	5	1·0 W	175·6	0·5
0·08–0·18	0·3–0·6	5	0·5 Mo	172·8	1·3
0·08–0·18	0·3–0·6	2	0·5 Mo	124·3	0·5
0·08–0·18	0·3–0·6		0·5 Si	173·5	0·6

the components are removed from the retort. Such a treatment will improve ductility and toughness of the coating as it will permit further diffusion and reduce the aluminium content of the surface.

The microstructure of a typical calorised mild steel shows an outer layer of alumina, a region of iron-aluminium phase and the base metal. The alumina layer is formed by the oxidation of the aluminium rich surface and this zone will reduce further oxidation. Calorised steel and cast-iron components can be satisfactorily used at elevated temperatures up to approximately 925° C. The excellent scaling resistance of calorised steel is shown in Table II. Resistance to sulphurous gases is also pronounced and the treatment offers a valuable alternative to the use of alloys which are particularly vulnerable to sulphurous fumes.

Fabrication of calorised iron and steel is not practicable even if carried out at a high temperature so that its use is restricted to such parts as conveyor chains, frames of heat treatment furnaces, baffle plates, parts in ore treatment furnaces like the Wedge roaster, heat exchanger components, etc., where full advantage can be taken of its resistance to elevated temperatures and sulphurous gases.

Acknowledgment

Acknowledgment is made to Metallisation, Ltd., and Coated Metals, Ltd., for their kindness in providing photographs for reproduction:

REFERENCES

1 *Proc. A.S.T.M.*, 1944, **44**, 92–109.
2 Ballard, W. E., *Chem. and Ind.*, 1955, 1606–1611.
3 Hughes, M. L., and Moses, D. P., *Metallurgia*, 1953, **48**, 105–122.
4 Gittings, D. O., Rowland, D. H., and Mack, J. O., *Trans. A.S.M.*, 1951, **43**, 587–610.
5 Stroup, P. T., and Purdy, G. A., *Metal Progress*, 1950, **57**, 59–63, 128, 130.
6 Gittings *et al.*, *loc. cit.*
7 *Steel*, 1957, **140**, (5), 105–106.
8 Sprowl, *Wire and Wire Prod.*, 1956, Oct. 31 (10) 1160–1163; 1273–1277.
9 Whitfield, M. G., and Sheshunoff, V., *Materials and Methods*, 1945, **22**, 1090–1096.
10 Collins, F. R., *Iron Age*, 1952, Jan. 17th, **169**, 100–101.
11 Sayles, B. J., "Metals Handbook," A.S.M., 1948, 703–704.

News in Brief

ORDERS have been received by Film Cooling Towers, Ltd., of Richmond, Surrey, for natural draught water cooling towers to be erected at Richborough power station, Kent, and the new Spencer Works of Richard Thomas and Baldwins, Ltd., near Newport. The latter towers are to serve the power station and blast furnace and gas cleaning plants. Two multi-cell induced draught water cooling towers are to be erected at the same works for the oxygen plant.

A NEW Scottish sales and service centre of the Griffin & George group was opened recently at Braeview Place, Nerston, East Kilbride, Glasgow.

THE gas atmospheres division of the Incandescent Heat Co., Ltd., has recently received a contract worth approximately £55,000 for equipment to be installed in a large Belgian steelworks. It is for three gas generators, each capable of producing 10,000 s.c.f.h. of a nitrogen/hydrogen mixture, and will bring the number of Incandescent nitrogen generators operating overseas up to nineteen—nearly 30% of the total production.

DOUBLE volute horizontal single-stage centrifugal pumps are to be made by the David Brown Foundries Division to the designs of The Bingham Pump Co., of Portland, Oregon, U.S.A., and marketed in the whole of the eastern hemisphere, with the exception of Australia, New Zealand, and part of Japan.

Two contracts totalling £362,000, have been placed with The General Electric Co., Ltd., by Richard Thomas & Baldwins, Ltd., for the new Spencer Works at Llanwern, near Newport, Monmouthshire. One covers nine 1,500 kW., 460 V., steel-tank mercury-arc rectifiers with associated transformers and earth-leakage and regenerative control panels. These rectifiers will be sited at strategic points in the plant to provide power for cranes and mill auxiliaries. The other is for the complete electrical equipment for a 62-in. wide continuous pickle line.

WITH rapidly growing sales to Northern Ireland, Albright and Wilson (Mfg.) Ltd., has opened a sales office at Imperial Buildings, 72, High Street, Belfast (telephone No: Belfast 32312; telegraphic address: Albriwil-Belfast).

WILD-BARFIELD ELECTRIC FURNACES, LTD., have nearly fifty furnaces on order for India, varying from small laboratory muffles to production units. Included in export orders to Belgium is one for a Wild-Barfield/NRC Model 2801 C crystal pulling furnace, while an order has been received for a large high temperature furnace destined for the Royal New Zealand Air Force. Laboratory and toolroom equipment is also being manufactured for Canada by Wild-Barfield.

ALUMINIUM, LTD., has established two new fabricating plants, one in Jamaica and one in Trinidad, to produce corrugated aluminium sheet and ancillary rain water goods for the local markets. The two factories together have an annual corrugated sheet capacity of about 3,000 tons: they will both use Alcan aluminium.

WALKER, CROSSWELLER AND CO., LTD., of Cheltenham, have opened a new office block in the town. This houses their sales and service departments, which retain the old telephone number (Cheltenham 56317) and address. Departments at the factory (accounts, works offices, buying and publicity) have a new number: Cheltenham 56366.

To accommodate the increase of staff due to rapid expansion, Union Carbide, Ltd., moved their head office to Union Carbide House, 8, Grafton Street, London, W.1. The headquarters of the chemicals, alloys, polyethylene and kemet divisions will also be in this building.

United Steel's New Headquarters

Transformation of Century-Old Building

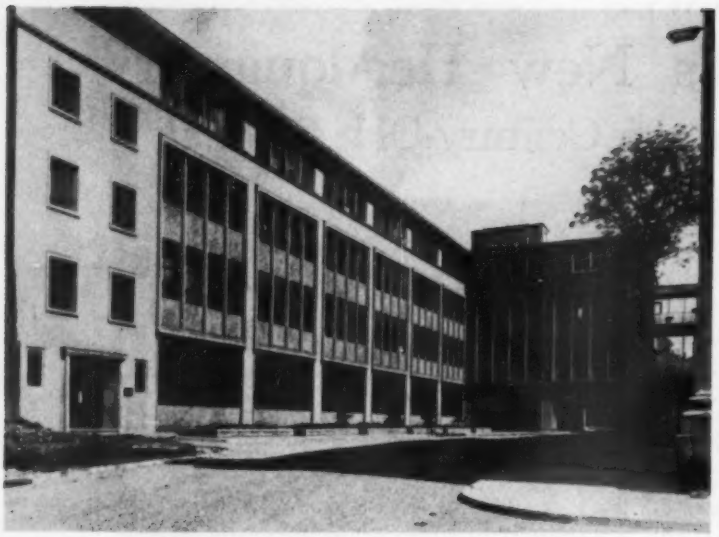
Only minor alterations have been made to the front elevation of The Mount, which was built in 1834. The bowling green in the foreground is on the roof of the car park.

THE head office of The United Steel Cos., Ltd., previously situated in a number of converted private houses in Westbourne Road, Sheffield, was transferred to new headquarters at The Mount, Broomhill, during January of this year. Here, about a hundred yards from the old premises, there is accommodation for a staff of approximately 150 people, some of whom are housed in The Mount itself, a 126-year-old building which has undergone intensive internal reconstruction, while others are accommodated in an entirely new four-storey block and interconnecting wing which have been built behind the main building.

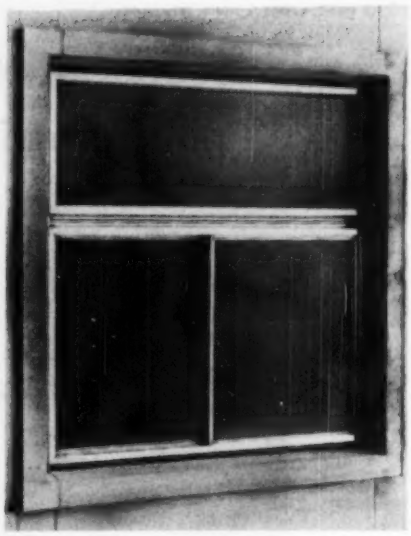
Underground car park for some 60 cars: a staircase leads to the main building and lifts to other floors.

Designed by William Flockton, a well-known Sheffield architect, The Mount was built in 1834 as a block of eight private houses sharing a common pillared facade in the classical style. One of the first occupants was James Montgomery, the hymn writer, journalist and sociologist, who helped to found most of the organisations for intellectual, moral and social improvement which existed in the town at the time of his death in 1854. John Holland was another local literary celebrity who lived at The Mount: a friend of Montgomery, he followed him as editor of the *Iris* weekly newspaper. Industrialists, headmasters, ministers and stationmasters were among those who lived at The Mount at various times. Subsequently, it was acquired by John Walsh, Ltd., who used it as their business premises after the 1940 blitz had destroyed their large department store. When the new store building was completed a few years ago, Walsh's sold The Mount to United Steel, and work began on the conversion and addition to the premises in May, 1958. The architects were J. Mansell Jenkinson & Sons, and the main contractors, Geo. Longden & Son, Ltd.

In general, it has been the intention of the architects to maintain the original character of the building, and the front façade was retained in its original form, whilst almost the whole of the internal structure was removed. Steel framework was introduced to strengthen the build-



The courtyard, showing the main elevation of the new block and the interconnecting wing which joins up with the original building.



A complete Fox stainless steel window

ing, most of the existing roof was removed, and steel trusses were introduced to provide a large open space on the top floor. A pre-stressed concrete hollow tile floor was supported on steelwork for most of the second floor, but elsewhere the existing timber floors were adjusted in height and covered with plywood to receive carpets. The external character of the building was maintained internally by the use of traditional detailing, arched fanlights providing borrowed light in the corridors, with panelled doors to the offices and plastered walls and ceilings. In addition to the boardroom and a number of private offices, it contains a well-equipped kitchen on the second floor, serving three staff dining rooms.

The New Wing

The new building is used wholly for office accommodation, special features including a spacious printing department, in which much of the general printing required by the company and its branches is undertaken, and a mechanised accounts department. The latter incorporates an I.C.T. 1202 electronic computer, which has been acquired to further the knowledge and application of new techniques to mechanised accounting. The building is steel framed, with pre-stressed hollow tile floors and *in situ* concrete staircases, the main elevators are faced with artificial stone, while the panels below the windows are exposed aggregate concrete. An interconnecting wing between the old and new buildings has, like the latter, been designed to harmonise with the rear elevation of The Mount.

An interesting point about the new building is that it is believed to be the first to use window frames completely fabricated in stainless steel and is, in consequence, free from any future external maintenance costs beyond periodic cleaning. As might be expected, Silver Fox stainless steel was used by the manufacturers, Morris Singer & Co., Ltd., of Walthamstow, London.

At the front of The Mount is an underground car park with accommodation for some sixty staff and visitors' cars. Linked with this car park is a hexagonal building which incorporates workshops, a wash-down bay and parking space for company cars. A bowling green and flower beds have been laid out over the car park in order to maintain the amenities of a largely residential neighbourhood.

Corrosion and Design

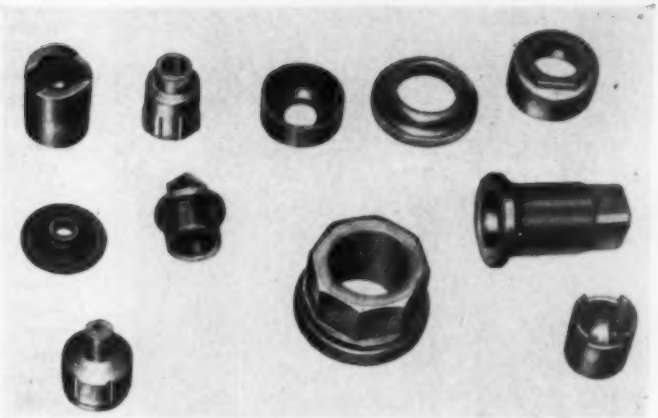
EXPERIENCE has shown that poor design of metal objects and structures can lead to serious damage through corrosion. Typical faults that lead to rusting are enclosed areas which form traps for condensed moisture, horizontal surfaces on which water can lie, and design details which cannot be reached for maintenance purposes.

The problem is clearly of practical importance and the Corrosion Committee of B.I.S.R.A. has, therefore, decided to investigate it. The scope of the research will be wide and will relate to structures and assemblies of all kinds. Moreover, the term "design" will be liberally interpreted so as to include not only design proper and general layout but also the choice of materials and of protective schemes. Structures will first be classified by type and environment; then examples of each type will be inspected from the point of view of corrosion design. Any undesirable features will be listed and practicable alternatives will be checked in consultation with engineering experts, and by experimental work, coupled where possible with service trials. It is hoped that, as a result, a code of recommendations will ultimately be published.

The investigation is of interest to architects, designers and engineers in many fields. Equally, their specialised knowledge and experience would help the investigators, who would welcome suggestions and comments on their proposals. Communications should be addressed to the Technical Secretary, Corrosion Committee, The British Iron and Steel Research Association, 140 Battersea Park Road, London, S.W.11.

Cold Forging

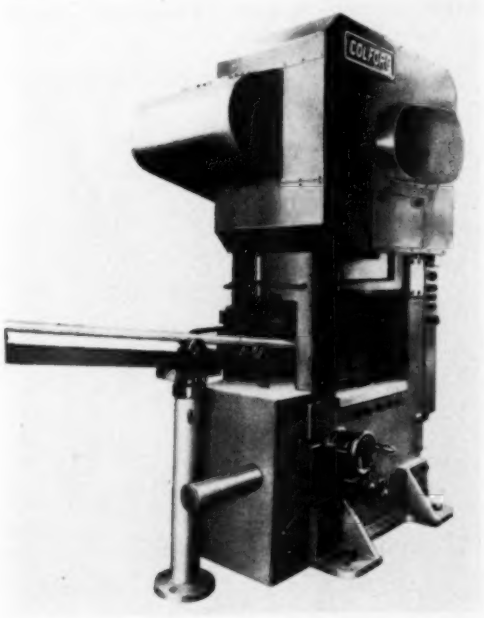
British Plant on Show at Hanover Machine Tool Exhibition



Range of components produced by cold-forging.

A COMPLETE cold-forging installation, claimed to be the first of its kind in the world, has been developed by a British company after extensive research and field trials. It takes the form of a complete production line capable of accepting raw barstock at one end and ejecting the finished article at the other end. The installation was shown in operation for the first time in public at the recent Hanover Machine Tool Exhibition. The equipment shown at Hanover is being manufactured by two companies, one in the United Kingdom (Cold Forging, Ltd.), and the other in Germany (A. Nothelfer u. Söhne)—both members of the Camp Bird group.

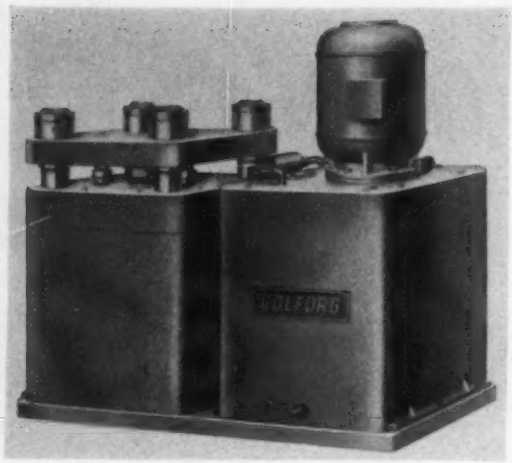
Cold-forging techniques make accurately controlled use of the plastic flow properties of metals in a complex shaping process. This not only requires machines of exceptional rigidity but also tools designed to withstand the enormous forces of cold-forging in continuous operation. The main effort of the Camp Bird companies engaged in this venture has been directed towards the production of equipment which will meet these stringent demands.



Cropping machine with automatic bar feed.

Although the process will not completely displace chip-forming machining methods, there is a wide range of components in general demand which can be mass-produced by cold-forging at costs which are substantially lower than those of conventional systems. This is due in part to the enormous saving of material—a saving of 50% or more is not exceptional when compared with chip-forming machining; in part to the high production rate of up to 5,400 per hour in the case of some components; and in part because components can be formed from relatively inexpensive low-carbon rolled stock, whose tensile strength is increased as a result of cold-forging—sometimes almost doubled—thus leading to the production of a high-grade article. New types of components are constantly being added to the growing list of applications of cold-forging, as designers become aware of the immense potentialities of the system. Complicated shapes can in many cases be produced in a single pass and often require no further finishing operation. The essential surface treatment remains effective after the completion of the components, which can then be stored for prolonged periods without any further protection against rusting or corrosion. Generally, this results in a simplification of storage problems and a further reduction of the costs involved.

Many attempts have been made during the last sixty years or so to achieve a practical application of the underlying principles and have met with varying—sometimes indifferent—success. However, it is only in comparatively recent years that the detailed scientific study of the parameters involved (studies with which the Camp Bird companies are intimately associated) led to the development of machines which in many aspects have completely revolutionised the manufacture of a vast variety of components, from simple nuts and bolts to highly complex parts which are currently being manufactured by this technique.



Preforming machine.

The range of cold-forging equipment shown in operation at Hanover incorporated a complete self-contained production line as well as some independent machines. Details of the machines on show are given below.

Cropping Machines.

One of the essential requirements of cold-forging is the production of an accurately sized blank which is obtained by initially cropping it from the bar. Of the two Type S. 25 cropping machines shown, one is a single purpose machine and the other a combination cropping/preforming machine. Both machines have a stroking rate of between 25 and 60/min., and both are capable of cropping pieces with a minimum length equal to one quarter of their diameter. The Type S 25 will accept barstock of up to 1 in. diameter, with a maximum cropping length of 2 in. The operation of the cropping machine is fully automatic, except for loading the raw stock on the automatic bar feed mechanism. The Type S 25 machine is capable of handling material with a shear strength of 12–42 tons/sq. in. Two further cropping machines—not shown on the stand—are the S 50 and S 75, which will accept barstock of up to 2 in. and 3 in., respectively.

Preforming Machine.

For certain applications, it is more convenient to separate the cropping and preforming operations. A separate preforming unit is available for such cases, particularly if a more intensive preforming is required than can be achieved by the combined machine. This machine is hydraulically operated and is intended for operation in conjunction with one of the "S" series of cropping machines. Outputs of between 1,200 and 2,400 parts/hr. are obtainable. The machine is completely self-contained but can be provided with suitable transfer units to permit operation in a production line. The floor space requirements are very modest and amount to only approximately 2 × 4 ft. The height and weight of the machine are approximately 4 ft. and 1 ton, respectively.

Deburring/Chamfering Machine.

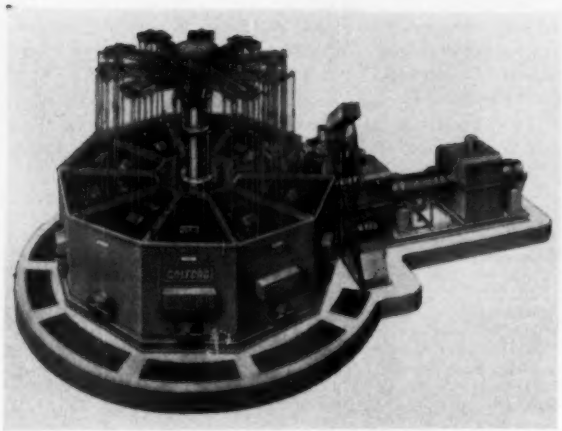
To prevent the inevitable cropping burr from being folded into the component during the cold-forging process, this burr is removed in the deburring/chamfering machine which also provides the component with a chamfer to facilitate entry into the die in the interests of a long tool life. Both the deburring and chamfering operations are of an orbital nature, i.e. the burr is removed from the outer edge of the component irrespective of its peripheral contour. This means that the machine can deal with oval shapes or components of different sizes and depths simply by appropriate adjustment of the roller type feed fingers and by setting the central cutter head to the desired depth. The demonstration machine is capable of accepting workpieces of between $\frac{3}{4}$ and 3 in. in diameter and between $\frac{3}{8}$ and $1\frac{1}{4}$ in. in length with an output rate of between 1,800 and 5,400 parts/hr. This range of machine is also available in other sizes, all models being self-contained with their own motorised drive and power feed. The overall dimensions of the demonstration model are 38 × 27 × 28 in.

Surface Treatment Plant.

To ensure reliable functioning of the entire cold-forging process, the cropped blanks must be given a thorough surface treatment, which may include degreasing, pickling, phosphating and lubrication, apart from loading and unloading of the work-pieces in batches. The surface treatment plant is of the "carousel" type with provision for ten treatment stages. This system is also built to suit customers' requirements and the effective load per treatment basket varies from 88 to 100 lb. One of the outstanding features of the system is the lubricating section, which is mechanically linked to the main plant but forms an independent unit to prevent fouling of the pickling and phosphating liquors with lubricants.

The surface treatment plant is equipped with a central rise-and-fall turntable from which the treatment baskets are suspended. While suspended in the baths, an end-on oscillation is imparted to the baskets to ensure that the entire surface area of each component is uniformly treated by the various fluids. The central pillar of the

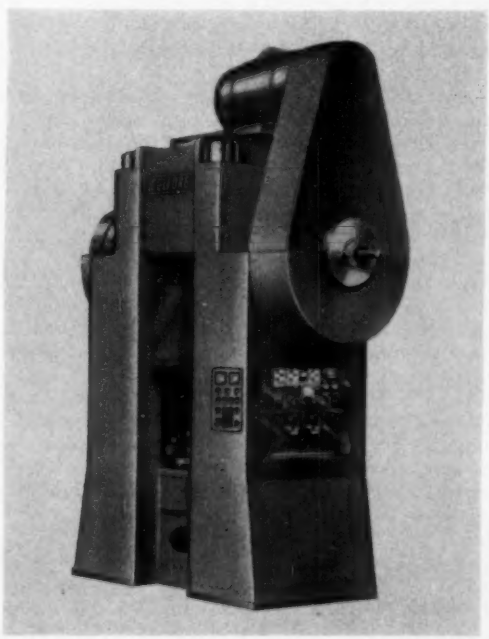
Deburring/chamfering machine.



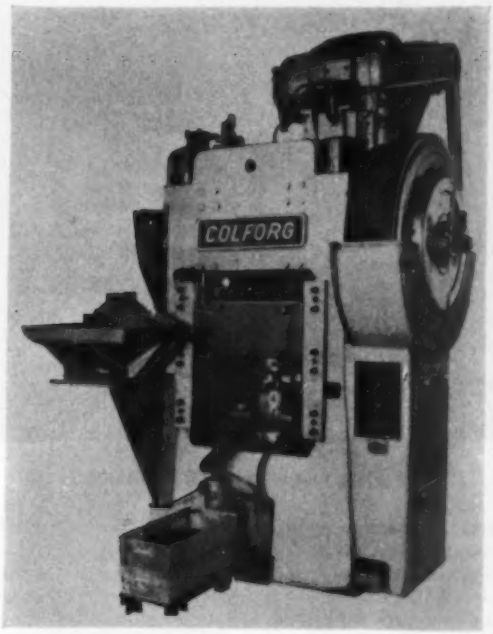
Automatic " carousel " type surface treatment plant.

turntable is hydraulically raised until the baskets swing clear of the individual bath walls after which the entire turntable is indexed by one bath station and once again lowered, so that the baskets, together with their charge of components, are moved from bath to bath in a strictly controlled operating cycle, whose timing can be varied to suit a wide range of individual requirements. Heating of the baths is thermostatically controlled and is provided by a new type of heating unit which can be easily removed for cleaning or maintenance.

On reaching the discharge station, the surface treated components are loaded into the lubricating unit, which operates on the screw conveyor principle. This system not only ensures that the lubricating process keeps pace with the other surface treatment operations, but the action of the conveyor screw forces the components to travel through the lubricant, so that they become thoroughly coated on all sides.



P 302 cold-forging machine, showing control panel and switchgear.



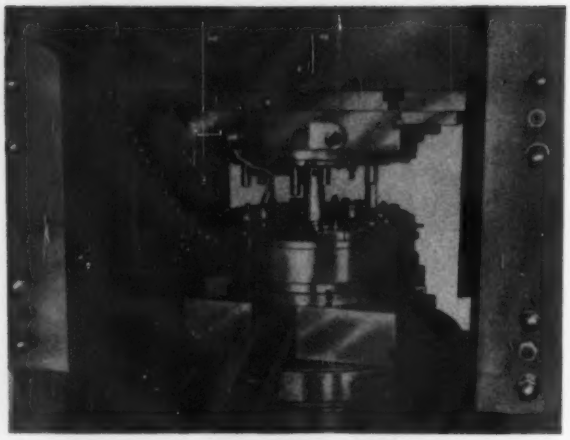
P 300 cold-forging machine with multi-station tool and automatic feed.

The extreme overall dimensions of the plant are approximately $23\frac{1}{2} \times 14\frac{3}{4} \times 9\frac{3}{4}$ ft. (weight approx. 20 tons). The overall throughput of components varies between 660 and 1,320 lb./hr., the dimensions of each basket being $27 \times 12 \times 19$ in. The plant can be supplied in different sizes, if necessary, without the lubricating system.

Cold-Forging Machine.

The final link in the production line is the cold-forging machine itself. Among the outstanding features of this machine are its extreme rigidity, which is obtained by the use of large cast steel sections which are held together by heavy pre-stressed tiebars. Stretch and distortion are thus reduced to levels far below those normally encountered in heavy machinery of this type. Power is transmitted to the ram (which slides in extra long guides) by a variable speed motor through a planetary reduction drive. By arranging the load to be distributed over several planet gears, the external dimensions have been reduced while the compact construction achieved in this manner contributes to the attractive styling of the machine. Another advantage of this type of drive is its low operating noise and smooth running characteristics.

The ejector system of the machine is cam controlled and was designed with a view to securing maximum flexibility to make the necessary allowances for a wide range of different components. The machine is also equipped with a pneumatically operated clutch and brake system designed to meet the special requirements of the process. A fully automatic lubricating system



Multi-stage tool with automatic blank feed.

reduces maintenance requirements of the machine to a minimum.

Special attention was paid to the design of the electrical control system. The entire control panel, mounted so as to eliminate the effects of vibration, is fitted in to the front of the machine in an easily accessible position. Apart from the contractors and switchgear for the automatic operation of the machine, the control system also incorporates a number of safety devices which effectively prevent any damage due to overloading or faulty operation.

Two models of these machines were shown : the Type P 300 and the Type P 302. The technical specifications of these two models are summarised below :

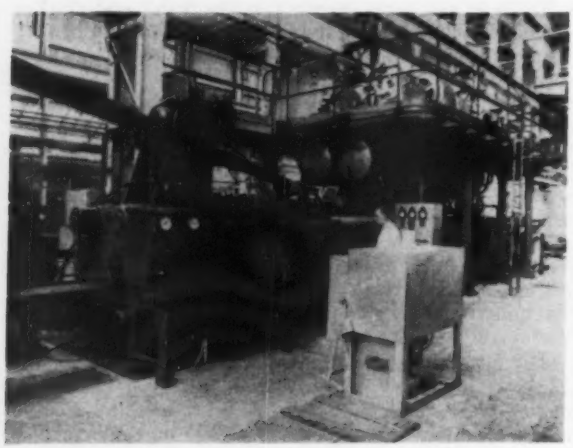
Type	*P 302*	*P 300*
Strokes per minute	45/60/90	60/75/90
Main motor	48/45/75 h.p.	20 h.p.
Width between uprights	28·5 in.	23·5 in.
Stroke	5 in.	4 in.
Max. ram adjustment	0·75 in.	0·39 in.
Max. distance between bed and ram (stroke up, ram adjustment up)	19 in.	17·75 in.
Bed area	28 × 31 in.	23 × 23 in.
Ram area	20 × 29 in.	23 × 27 in.
Ejector stroke	2 in.	
Overall dimensions	9 × 4·3 × 13·5 ft.	7 × 4 × 11 ft.
Weight approx.	20 tons	11 tons.

The Type P 302 machine was demonstrated on the stand with a four-station tool, but this is only one of the very large number of different set-ups possible on this machine. The demonstration Type P 300 machine was equipped with a special eight-station tool and automatic feed. Machines of this type will be available either in the standard versions or as special designs in various sizes to suit particular requirements.

£250,000 Export Order

A £250,000 CONTRACT for three horizontal extrusion presses has been awarded to Fielding & Platt, Ltd., of Gloucester, by Aluminium Menziken A.-G., of Switzerland. The presses, ranging in power from 750 to 1,500 tons, will each be operated from an independent hydraulic system powered by a battery of high-speed, motor driven oil pumps working at pressures up to 2 tons/sq. in.

The 750 ton press is designed chiefly for the extrusion of aluminium and aluminium alloy rods and solid sections. The two large machines, in addition to carrying out this type of work, will also be capable of producing tubes and hollow sections from pre-drilled or solid billets up to 8¾ in. in diameter by 27½ in. long. All three presses will incorporate a number of special features, some of them developed by Fielding & Platt and others based on the extensive experience of Aluminium Menziken, a concern employing well over 2,000 people and one of the leading fabricators of aluminium and aluminium alloy products in Europe.

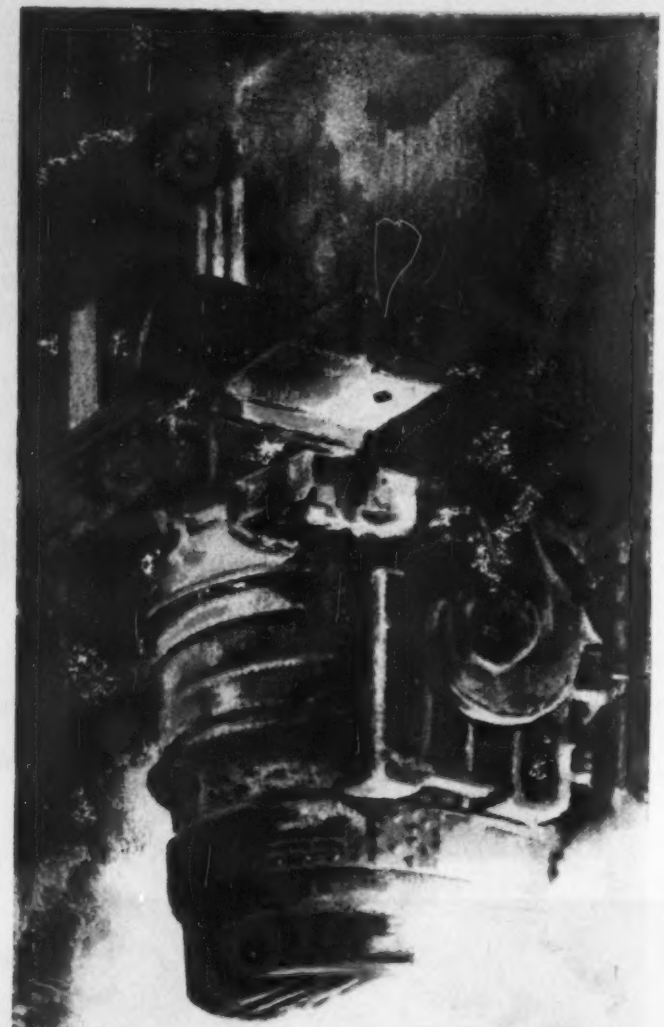


A Fielding 1,000 ton extrusion press similar to those ordered by Aluminium Menziken A.G.

Control of the presses and of the hydraulic circuit as a whole, will be from central control desks. All press motions will be fully interlocked but the controls will be specially arranged to give a choice of individual hand control of each motion or of automatic sequence control. The presses and their controls have been designed for operation with the absolute minimum of labour, and special attention has been paid to the die changing facilities in order to cut down the non-productive time in each press cycle. A further interesting feature is the provision of electrically heated die holders for maintaining the die temperature, not only during actual extrusion, but also when the die is in the " out " or " waiting " position. Each of the machines for Aluminium Menziken will be equipped with fully-integrated billet and pad loading devices, discard and pad separating and ejector units, etc., the controls for which are arranged, either for use within the automatic press cycle, or for independent operation as required.

WICKMAN, LTD., have assumed the sole selling rights in the U.K. for the range of machine tools produced by The Gisholt Machine Co., Madison, Wisconsin, U.S.A., and its associated subsidiary company Gisholt Machine Co. (Great Britain) Ltd.

Heat treatment
Cucumbers grow fine and ripe in the controlled heat of the greenhouse — and metal parts receive the best heat treatment in 'Cassel' salt baths.
With salt baths as with greenhouses, what counts is experience. The 'Cassel' Heat Treatment Service has long experience in carburising, heat treatment, tempering, martempering and austempering.
ICI
Write to:
Imperial Chemical Industries Ltd.,
London, S.W.1.



NOVO

(50% 60% & 70% Al_2O_3)

TRADE NAME FOR DEPENDABILITY IN REFRACTORIES

Developed specifically to withstand the severe conditions in modern furnace practice, the use of NOVO brands leads to production economies.

The Bonnybridge range of high grade firebricks includes CALDER L for steel ladles and OCTO, CALDER and BONNYBRIDGE BRAND for various furnace applications.

CEMENTS PLASTICS CASTABLES

A wide variety includes the BONCRETE Castables devised for all temperatures in modern metallurgical practice.

OUR TECHNICAL ADVISORY SERVICE IS FREELY AVAILABLE

BONNYBRIDGE SILICA & FIRECLAY CO. LTD. BONNYBRIDGE SCOTLAND

Telephone : Bonnybridge 227 · Telegrams : "Silica," Bonnybridge.

NEWS AND ANNOUNCEMENTS

Symposium on Steels for Reactor Pressure Circuits

The Iron and Steel Institute is organising a symposium on Steels for Reactor Pressure Circuits, to be held at the Hoare Memorial Hall, Church House, Great Smith Street, London S.W.1, from Wednesday to Friday, 30th November to 2nd December 1960. It will be included in the activities of the British Nuclear Energy Conference, of which the Institute is a member.

The provisional programme is as follows :

Wednesday, 30th November

9.30—10.30 Opening session and introductory lecture by Sir Leonard Owen (U.K. Atomic Energy Authority)

10.30—12.45 *Session I—High-Temperature Properties*
Presentation and discussion of :

The high temperature mechanical properties of the steels used in gas-cooled reactorpressure vessels, by J. M. Robertson (C. A. Parsons, Ltd.) and R. W. Nichols (U.K.A.E.A.)

Metallurgical aspects of creep, by J. Glen (Colvilles, Ltd.) and J. D. Murray (United Steel Cos., Ltd.)

The subcritical graphitisation of steels and related alloys, by J. E. Harris, J. A. Whiteman, and A. G. Quarrell (Sheffield University).

2.45—5.30 *Session II—Corrosion*
Presentation and discussion of :

The oxidation of reactor steels in carbon dioxide, by L. E. Benson *et al.* (A.E.I. (Manchester), Ltd.)

The corrosion of pressure circuit materials in boiling and pressurised water reactors, by F. L. LaQue and M. A. Cordovi (International Nickel Co., Inc.)

The corrosion of steels in liquid sodium, by C. Tyzack (U.K.A.E.A.)

Thursday, 1st December

9.30—11.30 *Session III—Fabrication Aspects*
Presentation and discussion of :

Metallurgical problems associated with engineering and fabrication of gas-cooled reactor pressure vessels, by W. C. Holliday and M. J. Noone (Whessoe, Ltd.)

Fabrication of the reactor vessel heat exchanger and circuitry for the Dounreay fast reactor, by P. K. Richardson (John Thompson Water Tube Boilers, Ltd.)

(It is hoped also to include a paper on fabrication in water-cooled reactors)

11.30—12.45 and 2.45—5.00 *Session IV—Irradiation Effects*
Presentation and discussion of :

Theoretical aspects on irradiation damage and brittle fracture in steel pressure vessels, by A. H. Cottrell (Cambridge University)

The effects of neutron irradiation on the ductile-brittle transition temperature of some pressure-vessel steels, by D. R. Harries (A.E.R.E.), C. Judge (Admiralty Materials Laboratory), and R. W. Nichols (U.K.A.E.A.)

Practical neutron dosimetry for steel irradiation studies, by L. E. Steele (U.S. Naval Research Laboratory).

Studies of radiation effects and recovery of notch ductility of pressure-vessel steels, by J. R. Hawthorne (U.S. Naval Research Laboratory)

Mechanical properties of irradiated steels by R. G. Berggren (Oak Ridge National Laboratories)

Influence of some metallurgical variables on irradiation embrittlement of ferritic steel, by L. P. Trudeau (International Nickel Co., of Canada, Ltd.)

Friday, 2nd December

9.30—12.45 and 2.45—4.30 *Session V—Steels for Future Reactors*
Presentation and discussion of :

Progress in development of some improved steels for reactor pressure vessels, by I. M. Mackenzie (Colvilles, Ltd.)

The development of a high-tensile plate steel for use at elevated temperatures and pressures, by T. F. Pearson and M. Z. de Lippa (Consett Iron Co., Ltd.)

Steels for nuclear power plant, by K. J. Irvine and J. D. Murray (United Steel Cos., Ltd.)

The effects of niobium on the properties of low-alloy steels, by J. E. Russell (English Steel Corporation, Ltd.)

The papers for the symposium are to be preprinted and will appear in due course, together with reports of the discussions, in the Institute's Special Report Series. The volume will be supplied at a price to be announced later ; one set of preprints will be sent to all those whose order for a bound volume is received by the Secretary before the meeting. Preprints of papers will not be available separately.

Foundry Courses

Since 1955 the training committee of the Council of Ironfoundry Associations has arranged residential courses on foundry supervision which are designed to show the close link between good technical and good man management. Following requests from member companies and associated bodies, it has now been decided to provide short courses, each of one week's duration, which concentrate on the technical and operational aspects of iron founding. Two such courses are at present planned, dealing with foundry metallurgy and cupola operation, and with moulding machines, moulding materials and defects. The next of the foundry metallurgy and cupola courses will be held at the Grove Hotel, Buxton, Derbyshire, commencing Monday, November 7th, 1960. The cost, which includes accommodation and all meals is 17 guineas. Further particulars may be obtained from The Training Section, The Council of Ironfoundry Associations, 14 Pall Mall, London, S.W.1. (Tel. : WHItehall 7171.)

G.K.N. Group Changes

Mr. C. R. Wheeler, C.B.E. is relinquishing the chairmanship of Guest Keen Iron & Steel Co., Ltd., and his directorships and executive appointments with the G.K.N. group at the end of the year, in view of his acceptance of another appointment. He will, however, remain a director of Guest, Keen & Nettlefolds, Ltd.

For administrative reasons Guest Keen Iron & Steel Co., Ltd., will change its name on January 2nd, 1961, to G.K.N. Steel Co., Ltd., and will acquire on that date the undertakings and assets of Brymbo Steel Works, Ltd., John Lysaght's Scunthorpe Works, Ltd., and The

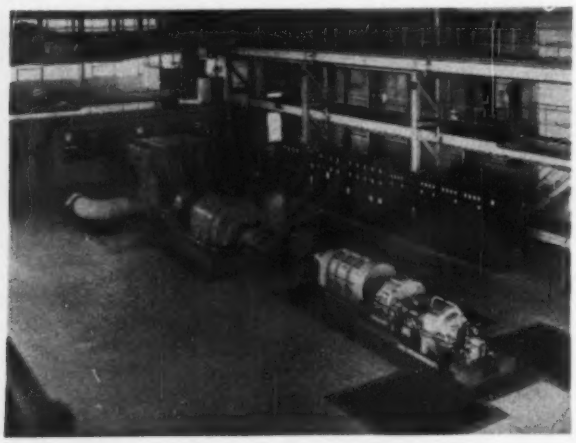
Scunthorpe Rod Mill, Ltd., which separate companies will then be liquidated. The board of G.K.N. Steel Co., Ltd., will be: Mr. K. S. Peacock (chairman), Mr. H. W. A. Waring, C.M.G. (deputy chairman and managing director), Mr. D. Bruce-Gardner and Mr. E. V. Callin (managing directors responsible for Lysaght's Scunthorpe Works), Mr. E. Davies (managing director responsible for Brymbo Steel Works), Mr. L. R. P. Pugh (managing director responsible for Guest Keen Iron and Steel Works), Mr. N. R. R. Brooke, C.B.E., Mr. R. P. Brookes, Sir John Green, Rt. Hon. Aubrey Jones, M.P., and Mr. E. C. Lysaght. It is intended that the three works will be operated under the same management as the existing separate companies, whose directors will become local directors of the G.K.N. Steel Co., Ltd., under the chairmanship in each case of Mr. H. W. A. Waring.

Tennant Memorial Lecture

THE Society of Chemical Industry announces that Professor A. R. Ubbelohde, F.R.S., (Professor of Thermodynamics, Imperial College of Science and Technology, London) will deliver the Fifth Charles Tennant Memorial Lecture entitled "Melting and Freezing." in the Royal College of Science and Technology (Room 24), George Street, Glasgow on Friday, 4th November, 1960 at 6 p.m. All interested persons will be welcome.

Northern Aluminium's Name Change

NORTHERN ALUMINIUM CO., LTD., was incorporated more than fifty years ago as the principal fabricating company of Aluminium, Ltd., the Canadian primary aluminium producer today responsible for about one fifth of the whole free world production. The name was, in fact, that given to the parent company when it was first established in Canada at the beginning of this century, and it has survived on this side of the Atlantic until a month ago. Now—on September 16th to be precise—the name has been changed to Alcan Industries, Ltd. This new name involves no change of ownership, manufacturing activity, or sales policy: its purpose is simply to identify the company clearly as a member of the Aluminium, Ltd., of Canada enterprise—Alcan for short. Over the years, the company's products have become well known under the Noral mark, and it is proposed to continue the use of this trade name.



Part of the first tonnage oxygen plant owned and operated by a steel company in Great Britain. The plant, built by Air Products (Great Britain) Ltd., in association with The Butterley Co., at Stewarts and Lloyd's Corby works—incorporates the latest developments in "low pressure cycle" oxygen plant design and has an output of 200 tons per day.

Nickel-Chromium Plating Symposium

ORGANISED by the London branch of the Institute of Metal Finishing, a symposium on Nickel-Chromium Plating will be held in the Recital Room of the Royal Festival Hall, London, S.E.1, on Wednesday, November 16th, 1960. Admission is by ticket only, but the branch extends a cordial invitation to members of all I.M.G. branches and their guests to attend. Tickets for the symposium are 37s. 6d., but there is no charge for admission to a small exhibition illustrating plant and processes for nickel and chromium plating to be held in the Royal Festival Hall on the same date. Tickets for the symposium and/or the exhibition can be obtained from Mr. S. W. Baier, Hon. Treasurer, I. M. F. London Branch, 9E Cleveland Road, London, W.13.

I.S.I. Autumn Meeting

THE technical sessions at this year's autumn general meeting of the Iron and Steel Institute, will consist of two short symposia, covering two of the wide range of interests covered by the Institute's activities. The meeting will be held at Church House, Great Smith Street, London, S.W.1 on Tuesday and Wednesday, 29th and 30th November 1960.

"Fluid Flow in Furnaces and Converters" is the subject of the first, which is devoted to the aerodynamic and hydrodynamic aspects of the design of furnaces and converters in use in iron and steelworks. Papers from France, Germany, the Netherlands, Russia, and the U.S.A., as well as from Britain, deal with the application of aerodynamic and hydrodynamic principles to the design of open-hearth furnaces, soaking pits, and oxygen-blown converters.

The physical metallurgist is catered for by the other symposium, the subject of which is martensite. This will consist of three sessions, devoted to the structure, kinetics, and properties of martensite, respectively. The discussion will be based on a series of key papers from university and industrial laboratories in the U.K. working on this subject.

Titanium Prices Down

THE Metals Division of Imperial Chemical Industries, Ltd., has announced further major reductions in the basic prices of their wrought titanium. The cuts, affecting deliveries after 1st November next, range from 15% for rod, extrusions and commercially pure sheet, to 10% for plate, wire and alloy sheet. Apart from its being incorporated in increasing quantities in modern high-performance aircraft, I.C.I. have successfully developed its use in other industries, notably chemical engineering. The consequent increase in demand, and technical improvements resulting from intensive research and development work, have made possible this further stage in I.C.I.'s declared policy of reducing the price of wrought titanium whenever greater throughput justifies it.

Cardiff Metals Exhibition

THE Mond Nickel Co., Ltd., is presenting an exhibition at the South Wales Institute of Engineers, Park Place, Cardiff, designed to interest all concerned with engineering problems involving the use of metals. The main emphasis of the exhibition will be upon the properties of nickel-containing materials and the platinum metals. For convenience, the exhibits, displays and demonstrations will be divided into seven sections relating to: the properties of metals at high, normal and sub-zero temperatures; metals versus corrosion; metals for surface protection; metals with special magnetic, expansion or chemical properties; and methods of fabrication. Another large section will feature nickel and chromium plating to the new British Standard.

The exhibition will be open from 1st to 4th November, and each day at 11 a.m. and 3 p.m. lectures will be given by members of the company's development and research department: ample opportunity will be afforded for technical discussions both at the lectures and in the exhibition rooms. Films will be shown at other times during the day and a programme of the lectures and film showings can be obtained from The Mond Nickel Co., Ltd., 20 Albert Embankment, London, S.E.11

Metal Finishing Dinner

THE Institute of Metal Finishing is to hold its first annual dinner at the Cafe Royal, Regent Street, London, W.1., on Monday, December 5th. This will be preceded by the annual general meeting at 2.30 p.m. and the Hothersall Memorial Lecture—to be delivered by Professor J. W. Cuthbertson—at 3.30 p.m.

Personal News

MR. W. A. ANKERSON has joined the board of Associated Electrical Industries (Woolwich), Ltd., as assistant managing director. Mr. Ankerson will relinquish his appointment as general manager, A.E.I. home district offices, and will cease to be a director of Associated Electrical Industries Overseas, Ltd.

MR. A. W. WALLBANK, managing director of Ionic Plating Co., Ltd., the metal finishing division of the G.K.N. group of companies, received the Gold Medal award, at the American Electroplaters' Society's Convention at Los Angeles, on Monday July 25th, 1960. The prize is the Carl E. Heussner A.E.S. Gold Medal Award (the Society's highest paper award) for his paper entitled "Barrel Plating with Special Consideration to Protection of Thread Diameters."

MR. W. C. BELL a director of Stewarts & Lloyds, Ltd., has been appointed to the board of directors of The Wellman Smith Owen Engineering Corporation, Ltd., along with MR. D. L. CAMPBELL, managing director (sales) of Metallurgical Equipment Export Co., Ltd.

MR. J. LIPSCOMBE has been appointed a London representative of Thomas Millington & Co., Ltd.

THE UNITED STEEL COS., LTD., announce that MR. E. B. REES, acting on medical advice, has resigned as export manager and his resignation has been accepted with regret. Mr. Rees will continue to act as consultant to the company on export matters. MR. H. A. A. WHILE, manager of the company's London office, has been appointed general export manager, and will continue to be responsible for the railways department. MR. F. A. PLATTS succeeds Mr. While as London office manager.

ASSOCIATED ELECTRICAL INDUSTRIES, LTD., announce the appointment of MR. J. A. BROOKS, as divisional assistant manufacturing manager, motor and control gear division. Mr. Brooks will retain, for the time being, his position as superintendent, large industrial machines department, Mosley Road Works, Manchester, but will eventually be located at Rugby to devote his full time to his new duties.

DR. T. F. WEST, has been appointed Editor of *Chemistry and Industry*, the weekly news organ of the Society of Chemical Industry.

SAMUEL FOX AND CO. LTD., a subsidiary of The United Steel Cos., Ltd., announce that MR. G. THICKETT, who has been combining his duties as works manager (heavy departments) with those of billet mill manager, will relinquish the latter appointment. MR. E. HAMPSHIRE, at present production controller, is appointed billet mill manager, MR. N. P. BROMILEY becomes production controller, and MR. C. GRAY, assistant to the bar and rod mill manager, becomes assistant manager, bar and rod mill.

MR. H. R. THIELE has been appointed as deputy to the advertising manager of The Morgan Crucible Co., Ltd. Mr. Thiele was for many years personal assistant to the advertising manager of the Champion Sparking Plug Co., Ltd.

HADFIELDS, LTD., announce the appointment as local directors of MR. D. R. WARD, assistant secretary of the company and secretary of several of the subsidiary companies in the group, and Mr. A. W. GURNEY, chief cost accountant of the company.

MR. W. J. FRY, a director of Solartron Research and Development, Ltd., has been appointed sales director and commercial manager of Solartron-John Brown Automation, Ltd., manufacturers of the Gompertz automatic warehouse with world rights, including the U.S.A., for the automatic supermarket.

UNION CARBIDE ALLOYS DIVISION announces that MR. M. A. CLIFTON has joined the outside sales staff as a representative in the Southern area. Mr. Clifton will be based on the head office in London.

MR. H. M. HENDERSON, at present managing director of Unisteel Structural (Pty.), Ltd., of Cape Town, South Africa, has been appointed director and general manager of the Workington Iron and Steel Co. branch of The United Steel Cos., Ltd. He succeeds MR. T. S. KILPATRICK who, as already announced, became director and general manager of the Steel, Peech and Tozer branch on August 1st. Mr. Henderson will take up his new appointment in November, 1960, with the intention of relinquishing it on June 30th, 1962. MR. T. SANDERSON, at present director and general works manager of Workington Iron and Steel Company, has been appointed deputy general manager, to take effect from August 1st, MR. H. DARNELL, at present chief engineer, succeeds Mr. Sanderson as general works manager and has been made a director.

THE board of CIBA (A.R.L.), Ltd., have with regret accepted the resignation of DR. N. A. DE BRUYNE from the position of managing director at the end of 1960: he will, however, remain on the board. On and after

January 1st, 1961, Mr. R. F. G. Lea, O.B.E., will become deputy chairman of the company. Mr. Lea and Mr. D. A. Hubbard will also become joint managing directors.

Mr. C. F. Pagnamenta, O.B.E., secretary of Guest Keen Iron and Steel Co., Ltd., has been elected a director. He joined the company in October, 1957 as chief accountant and became secretary in August, 1959.

Associated Electrical Industries, Ltd., have appointed Dr. D. C. Milner as editor of the new AEI technical journal *AEI Engineering*. He will take up his post at the end of the year. This publication, the first interim number of which appeared in May this year, has replaced the journals formerly published by British Thomson-Houston, Metropolitan-Vickers, Siemens Edison Swan and Henley's. It will deal with the technical work and research of the company as a whole and will cover all its products. As from January, 1961 it will be published monthly.

The Workington Iron and Steel Co. branch of The United Steel Cos., Ltd., announce a number of new appointments. Mr. G. Pott, works engineer, is now chief engineer; Mr. W. Hunter, blast furnace manager, is appointed ironworks superintendent, with responsibility for ore preparation and blast furnaces; Mr. F. Greenhalgh succeeds Mr. Hunter as blast furnace manager; Mr. J. D. Young, Bessemer manager, becomes assistant steelworks superintendent, and is succeeded as Bessemer manager by Mr. G. Forster, at present Bessemer shift manager.

Obituary

We regret to record the death of the following:

Mr. G. Archer, C.M.G., president of The Mond Nickel Co., Ltd., who, after a long period of indifferent health, was taken ill in his office and died in Westminster Hospital on Tuesday, September 20th, 1960. Mr. Archer was appointed president in July of this year, having been chairman of the company and its subsidiary, Henry Wiggin & Co., Ltd., since July, 1959. Born in 1896, Mr. Archer entered the Civil Service in 1913 and, apart from four years naval service during World War I, remained in it until 1948. During World War II, he was concerned mainly with raw materials, becoming head of the British Raw Materials Mission in 1945, and in recognition of his services in this field was appointed a Companion of the Order of St. Michael and St. George in 1945. Mr. Archer joined the Mond Nickel board in 1948, and became sales director in 1952 and managing director in 1955.

Sir Arthur P. M. Fleming, formerly director of research and education at Metropolitan-Vickers Electrical Co., Ltd., who died on September 14th, 1960, at his home near Shanklin, Isle of Wight. Sir Arthur, who was 79, was one of the group of engineers—later known as "the holy forty"—who went to the United States at the beginning of the century to be trained for positions at the new British Westinghouse (later Metropolitan-Vickers) works in Trafford Park. Later he formed the nucleus of a research department which has, from small beginnings, grown into an establishment employing several hundred people and enjoying a high reputation in the scientific and technological world. For his work on submarine detection during the 1914–18 war he was awarded the O.B.E., and later the C.B.E. An early pioneer in radio-communication work, Sir Arthur's department provided the location for the first Manchester broadcasting station of the B.B.C.—the old 2ZY—and several members of the staff took part in the early broadcasts. Under his guidance, considerable success was achieved in the high vacuum and high voltage fields, and in the development of demountable large-power thermionic valves which helped to make radar possible. He was associated with many scientific and industrial societies, and was a past-president of the Institution of Electrical Engineers, whose Faraday Medal he was awarded in 1941.

No less than in research, Sir Arthur made the name Metropolitan-Vickers known throughout the world in the field of education. He founded and developed the company's education department—a pioneering effort in this field which formed the basis of many similar schemes elsewhere—to provide training for all classes of young employee, whether the ultimate goal was employment as a skilled manual worker, a draughtsman or an engineer, the courses of theoretical and practical training being designed to be complementary to those provided by the evening institute, the technical college or the university. The M.-V. Ex-Apprentices Register, which outlines the subsequent careers of those who have passed through the education department's hands, is a fitting monument to A.P.'s work in industrial education, for which he received a knighthood in 1945.

Mr. Barrington Hooper, C.B.E., chairman of Industrial Newspapers, Ltd., who died on September 2nd, 1960, as a result of a coronary thrombosis. In 1926 he formed Industrial Newspapers, Ltd., in association with, among others, Mr. Harold Jeans, who later became chairman with Mr. Hooper as managing director. On Mr. Jean's retirement in 1955, Mr. Hooper also took over the chairmanship. As the years passed the company's journals grew in number and today include several in the metallurgical field. Mr. Hooper, who was 75, was a man of wide interests, largely concerned with the technical and industrial fields covered by these journals. He was, for instance, a member of the general council and of the finance committee of the Institute of British Foundrymen. A memorial service was held at St. Bride's Church, Fleet Street on September 20th.

Dr. C. E. K. Mees, F.R.S., Hon.F.R.P.S., the internationally famous photographic scientist, who died on August 15th, 1960, at his home in Honolulu, Hawaii, at the age of 78. Following work in photographic processes at University College, London, Dr. Mees was a partner in the Croydon photographic firm of Wratten & Wainwright, Ltd. In 1912 he accepted George Eastman's invitation to join the Kodak Co., and went to Rochester, New York, to organise and direct a research laboratory. After World War I, he became director of research and development for the company, and in 1923 was made a director. Over the years Dr. Mees received numerous scientific awards, including the Fellowship of the Royal Society. His interest in the country of his birth continued throughout his life. He was responsible for founding the research laboratory at Kodak, Ltd., in 1929, and he remained a member of the board of the company until his death.

is your pet a powder-compact type ?

Let's face it—your pet is a self-sintered type needing careful nurturing and a little patting and preening to help it toe the production line.

The discipline of uniform treatment in a Birlec furnace is the simple answer. These furnaces have all the attributes demanded by experienced powder metallurgists and they come in types and sizes to suit your pet product and production.

Birlec mesh-belt conveyor furnaces include straight-through and hump-back types specially adapted for sintering applications, with burn-off chamber, multi-zone control, low-stress conveyor drive and easily replaceable heating elements.

Ask your pet typist to write for more information.

BIRLEC *furnaces for every heat treatment*

AEI-Birlec Limited

Tyburn Road, Erdington, Birmingham 24

Telephone: East 1544 *Telex No: 33471*

SM.86194

LONDON · SHEFFIELD · NEWCASTLE-ON-TYNE · GLASGOW · CARDIFF

HOMOCARB ELECTRIC GAS CARBURISING AT MORRIS MOTORS

WE are indebted to Morris Motors Ltd. for the above photograph of their latest installation of Homocarb Electric Gas Carburising furnaces at their Engine Division at Coventry.

For many years the Morris Company has used these Homocarb furnaces at their several works. Making an original sale is a comparatively simple matter but this continued confidence after long years of experience provides convincing evidence of

PROVED EFFICIENCY

Rolls-Royce, Austin, British Timken, B.S.A., Caterpillar Tractor, Humber, International Harvester, Singer, Sperry Gyroscope, Vauxhall, Morris, Jaguar, Villiers, Hoffman, Leyland, Rotol, Vandervell, etc., etc., are among hundreds of users of Homocarb.

Send now for descriptive literature or a Technical Representative will visit you at your convenience

LEEDS NORTHRUP

INTEGRA, LEEDS & NORTHRUP LTD.

183 Broad Street, Birmingham, 15

Phone: Midland 1453/4 *Telegrams: Flometer, Birmingham*

British made in Birmingham

RECENT DEVELOPMENTS

MATERIALS : PROCESSES : EQUIPMENT

Nimonic 115

ADDITIONS to the Nimonic series of creep-resisting alloys have been marked in each case by improvements in their essential properties. Increments have been shown in life to rupture, permissible working temperature, or stress-carrying capacity, and it is easy to overlook the total advance that has been made since Nimonic 80 alloy was first used for turbine blades. Acceptance creep tests applied to the alloys are :

NIMONIC 80A : 21 tons/sq. in. at 750° C., with a minimum life to rupture of 23 hours;
or 17 tons/sq. in. at 750° C., with a minimum life to rupture of 75 hours.

NIMONIC 90 : 19 tons/sq. in. at 750° C., with a minimum life to rupture of 75 hours ;
or 12½ tons/sq. in. at 815° C., with a minimum life to rupture of 75 hours ;
or 9 tons/sq. in. at 870° C., with a minimum life to rupture of 30 hours.

NIMONIC 105 : 7 tons/sq. in. at 940° C. with a minimum life to rupture of 50 hours.

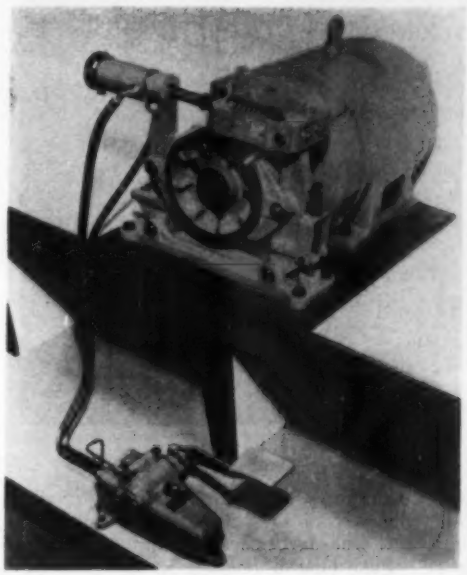
These impressive advances have all been made within a period of twenty years and it is therefore all the more remarkable that the introduction of a new alloy in the series, known as Nimonic 115, should disclose an even greater advance than has previously been made in one stage. This alloy is released against a test specification of 7 tons/sq. in. at 980°C., with a minimum life to rupture of 75 hours. Thus, comparison with the figures for the previous alloy (Nimonic 105) indicates a considerable increase in operating temperature plus a 50% increase in creep life.

The development of the alloy has been associated with a possible test requirement of 35 hours to rupture at a stress of 7 tons/sq. in. at 1,000°C., and although production quantities are not yet released against this criterion, the test target is a further indication of the level of properties offered in Nimonic 115 alloy. The production of a wrought alloy having properties hitherto obtainable only in the very advanced casting alloys is the outcome of years of specialised experience and the development of new techniques for casting and extrusion. Nimonic 115 alloy is now being supplied to several engine builders and is already used for the blades of certain of the most advanced gas-turbine engines.

Henry Wiggin & Co., Ltd., Thames House, Millbank, London, S.W.1

Hydraulic Brake

A new hydraulic Perigrip brake introduced by Associated Electrical Industries, Ltd., (Motor and Control Gear Division) is available in 8 in., 10 in. and 12 in. drum sizes with braking torques up to 400 lb. ft., and is specially suitable for long travel motions on overhead cranes. Many of the parts are interchangeable with those used on the company's range of electrically-operated brakes, but in place of the usual electro-magnetic device on the operating arm, the new brake



has a simple hydraulic receiving unit. This receiver is actuated by oil pressure delivered by a foot-operated transmitter unit to which the driver's brake pedal is attached. The hydraulic fitments are manufactured by Exactor, Ltd.

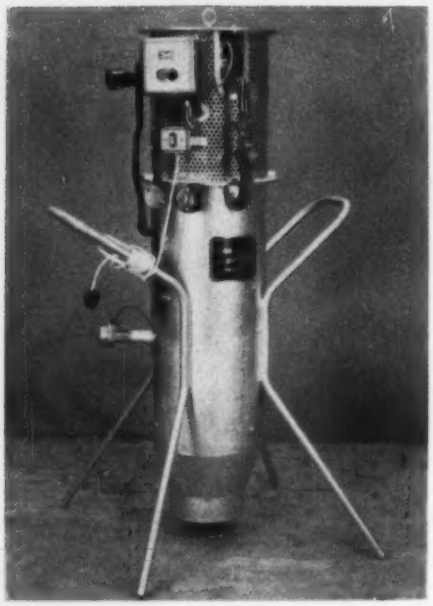
The brake is so constructed that the shoes are normally "off"; and by movement of the pedal, the braking torque can be applied and increased smoothly up to the maximum permitted by the brake mechanism. The advantage of this over the positive "snap" action of an electric brake when applied to the travel-motor of an electric crane, is that it minimises any tendency for the load to swing when the crane is stopped suddenly.

Associated Electrical Industries, Ltd., Motor and Control Gear Division, Rugby.

Portable Dryer

MODERN Furnaces & Stoves, Ltd., have recently introduced, and are now manufacturing and marketing, a new lightweight portable hot air unit—the Axial Jet-M—designed and developed by the North Western Gas Board. This new 140 lb. unit produces a high temperature and high velocity air stream for mould drying. The thermal output is 400,000 B.T.U./hr., the temperature range up to 400° C., and the hot air discharge rate 400 cu. ft./min. The large fan capacity ensures that all parts of the mould are evenly dried.

The dryer is easily transported by means of one lifting lug on the apex of the casing. It is designed to stand on its legs and project high velocity air downwards. The maximum heat output is obtained instantly, and when drying at high temperatures the



casing of the unit, with the exception of the outlet nozzle, remains cool as a result of the passage of air through the annular space around the combustion chamber. Push-button control is included by incorporating continuous high voltage ignition, and protection against electrical failure is provided by a solenoid valve in the gas supply.

Modern Furnaces & Stoves, Ltd., Booth Street, Handsworth, Birmingham, 21.

Magnox/Stainless Steel Welding

A GAS-WELDED sealing joint between Magnox—a magnesium alloy containing small amounts of aluminium, beryllium, iron and silicon—and stainless steel is being successfully made by the United Kingdom Atomic Energy Authority. This is the first time that these two materials have been joined in this way. This latest process, involving the use of Tinflux, was developed by the Sales Technical Service Department of British Oxygen Gases, Ltd., in co-operation with the U.K.A.E.A. and follows an earlier technique adopted for the welding of dissimilar metals.

The present application is carried out on special bolts used to secure canisters in position for deadweight load and pressure tests. Bolt stems of stainless steel are fitted with Magnox bushes under the heads. A "welded" seal is made between the bushes and the bolt heads. Recesses in the bushes form joints with the tops of the canisters and act as vacuum-tight seals during testing. The Magnox canisters are designed to hold radioactive material, and to operate within the atomic pile.

British Oxygen Gases lightweight Saffire oxy-acetylene blowpipes are used for the joining operation.

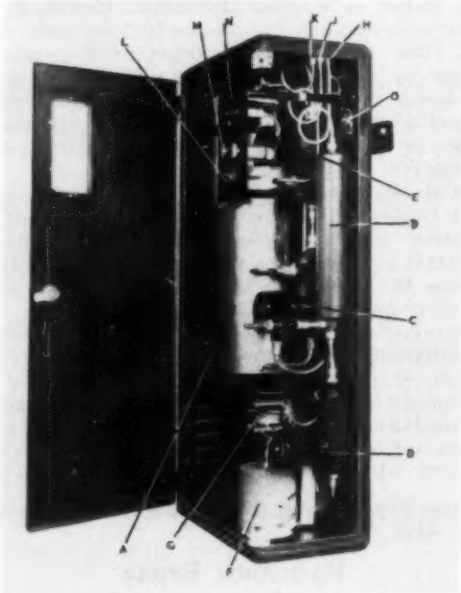
British Oxygen Gases, Ltd., Sales Technical Service Dept., North Circular Road, Cricklewood, London, N.W.2.

Pure Dry Hydrogen

THE Deoxo catalytic purifier has become widely accepted as an efficient and economical means of removing oxygen from gases. One very important use lies in the purification of hydrogen as an atmosphere for heat treatment and other applications. To meet the demand for a self-contained unit, combining the features of the Deoxo purifier with those of an automatically operated drying unit containing Linde Molecular Sieve, Engelhard Industries, Ltd., have produced the Deoxo Puridryer.

This unit, having a maximum capacity of 100 s.c.f.h., will purify normal commercial grade hydrogen to give a gas with an oxygen content of less than 1 part per million. By use of Linde Molecular Sieve as the drying agent it achieves a dew point as low as −100° F. (−73° C.) which enables the gas to be fed directly to a furnace. Operation and installation data for the Puridryer are as follows:

Capacity	100 s.c.f.h.
Maximum Operating Pressure	5 p.s.i.g.
Pressure Drop at 100 c.f.h.	1 p.s.i.g. approx.
Power Requirements	200-250 V., A.C., 200 W. (during re-activation)
Inlet and Outlet Connections	¼ in. B.S.P.
Re-activation of Drying Unit	Automatic: time required 5 hours
Installation	Wall or front of panel mounting
Overall Dimensions	32½ in. × 13½ in. wide × 8¾ in. deep



A	DRYING UNIT	H	GAS INLET
B	DEOXO CATALYST CHAMBER	J	GAS OUTLET
C	UPPER 3-WAY SOLENOID VALVE	K	STANDBY GAS INLET
D	LOWER 3-WAY SOLENOID VALVE	L	REACTIVATION SWITCH
E	2-WAY SOLENOID VALVE	M	PILOT LIGHT
F	CONVERTER	N	REACTIVATION CYCLE TIMER
G	TRANSFORMER	O	POWER CONNECTION

The Puridryer should be installed on the low pressure side of the gas supply line to avoid gas at pressures greater than 5 p.s.i.g.

The platinum metals catalyst used in the Puridryer to remove oxygen requires no re-activation, and unless poisoned by sulphur compounds, carbon monoxide, chlorine, and some organic compounds—which are rarely found in commercial hydrogen—should last indefinitely. The Puridryer may also be used with other gases such as nitrogen, argon, neon and saturated hydrocarbons, providing that two volumes of hydrogen are present in the gas to react with each volume of oxygen impurity to be removed.

*Engelhard Industries, Ltd., Baker Platinum Division, 52 High Holborn, London, W.C.*1.

Liquid Zinc Anti-Corrosive Compound

A NEW liquid zinc anti-corrosive composition for use on iron and steel and other metal surfaces, has been developed by the MacCleaster Chemical Co., Ltd.—a Powell Duffryn company. The new preparation has a base of chlorinated rubber and zinc dust of extremely small particle size, and among the important advantages claimed for it is freedom from rapid settling out. In the past, the combination of chlorinated rubber and zinc or other metals has created certain problems, one of which has been the rapid settling out of the composition or paint. The MacCleaster preparation requires no more than normal stirring before use.

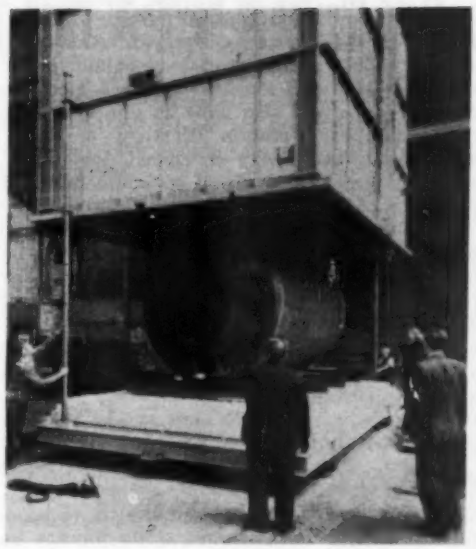
It can be applied by brush or spraying or by dipping, over rusted surfaces or even over surfaces which have been previously painted, subject only to some scraping or wire brushing. It is also of above average flexibility, abrasion resistant and although not specifically heat resistant, will withstand a dry temperature of 200° C. and a wet temperature of 120° C. It possesses excellent fire retardant properties, prevents "rust creep," is impervious to polluted atmosphere (industrial fall out), to sea and fresh water.

The manufacturers claim that the composition is equally efficient as a single coat system (as a primer, giving increased adhesive properties to the top decorative finish), making it particularly suitable in the protection of structural steelwork and for general industrial use. Its cathodic properties are especially important for marine application and since the dried film is non-toxic it can be used for the protection of water tanks and cisterns. It is now commercially available after an extensive period of field-testing.

*MacCleaster Chemical Co., Ltd., 8 Great Tower Street, London, E.C.*3.

Electric Stress Relieving Furnace

THE Shelley "Top-Hat" electric intermittent furnace, which has been so successfully employed for the past five years in the ceramics industry, is now being supplied to the engineering industries where, in its new and improved form, it is proving an efficient and extremely economical unit for the stress relieving of boilers, pressure vessels and other welded structures. The manufacturers claim that fuel costs of the "Top-Hat" furnace are nearly 75% less than those of oil- or coal-fired units, while the operating techniques provide the added advantages of simplified loading and space reduction. Further economies can be attained by the use of the furnaces during off peak periods when the factory would normally be closed down.



Courtesy of John Thompson (Wilson Boilers) Ltd.

With the "Top-Hat" principle, products are placed on the furnace base, tiered on racks if necessary, while the sides and roof of the furnace remain raised by a Geo. King Mammoth hoist block suspended from an overhead gantry. When ready for firing the top is lowered as one unit and placed in position over the products: in this way there is no danger of movement of the load. The base is constructed of prefabricated channel and steel plates insulated with firebricks through which electric heating elements are inserted. The upper section, or "top-hat", has steel plated sides, the inside being lined with insulation material attached by heat-resisting rods and hooks and lined with elements on all sides and the roof, the latter being constructed either as an arch or a flat top.

The heating elements are of a heavy gauge alloy; for specially high temperatures porcelain tubes are passed through the coils for added stability. All fixed wiring is carried out in heat and moisture resistant mineral insulated "Pyrotenax" cable. Heat control may be by means of transductors or saturable reactors, a non-electronic infinitely variable control which may be set to a programme by the use of a time-temperature programme controller. A galvanometer at the control panel feeds a light D.C. electric current to the transductor according to the predetermined programme curve. This method has proved completely reliable and the makers are prepared to guarantee control to within very fine limits.

Shelley "Top-Hat" furnaces are supplied in sizes varying from 15 cu. ft. to 2,600 cu. ft. and larger. Usually each plant is tailor made for specific requirement. All furnace equipment is completely fabricated in Shelley's factory and delivered complete to the customer ready for use with the minimum of site expense. Complete installation is undertaken by the manufacturers, including the necessary overhead gantry and King hoist.

Shelley Electric Furnaces, Ltd., Longton, Stoke-on-Trent, Staffs.

Gold Plating of Printed Circuits

THE ever increasing use of printed circuits in the electronics industry has created a demand for a gold plating bath that will not only produce hard, durable gold deposits but will also have no injurious action on plastic laminates. Johnson Matthey & Co., Ltd., announce that their newly developed Acid Hard Gold bath produces gold deposits of optimum durability on most grades of printed circuit and entirely overcomes the principal defect of conventional gold plating baths—failure of the laminate bond due to the effect of the high free-cyanide content of the plating solutions. Furthermore, gold electrodeposited from the new bath has a Vickers hardness in the range 120–130.

Acid Hard Gold is supplied as a concentrated solution, which is diluted to make up the plating bath. Insoluble anodes of platinum or platinum-plated titanium are used in the bath. Stainless steel anodes must not be used as corrosion of the steel leads to contamination of the solution. For like reasons, the bath should be contained in glass, earthenware or plastic vats.

The recommended cleaning method is to scour the work with a stiff bristle brush using pumice powder in water, which action will not only remove oxide film but also any traces of grease. In order to ensure good adhesion it is advantageous to deposit a thin layer of copper from a sulphate bath on work to be plated, though printed circuits with copper laminates may be plated direct. It is preferable, in all cases, to make the work cathodic before immersion in the bath to eliminate the possibility of forming chemical replacement deposits.

During the plating process the *p*H of the bath should be measured regularly with a *p*H meter and maintained within the range 6–7 by the periodic addition of a few drops of weak phosphoric acid solution. Relatively stress-free deposits are obtained by operating the bath at 50° C., or above, with a current density of not less than 3 A./sq. ft. The weight deposited is 5·15g./A.-hr.

Johnson, Matthey & Co., Ltd., 73-83 *Hatton Garden, London, E.C.*1.

CO_2 Welding

UP to 12 lb./hr. of metal deposited is claimed for the Philips manual CO_2 welding equipment, now in full production after extensive field trials. This is at least three times the accepted rate of deposition by an efficient welder using conventional electrodes. It is also stated that all-positional welding is practicable using conventional D.C. power sources. Overhead, vertical up, vertical down, and downhand welding can all be done in sequence without change of current and voltage. Some firms using the trial equipment are stated to be confident of recovering their capital outlay within twelve months.

The new equipment, marketed in this country by Research and Control Instruments, Ltd., consists of a compact three-wheeled unit carrying wire reel and wire feed mechanism, two CO_2 gas cylinders with all necessary gas and electrical controls, and an associated hand welding gun to which the welding wire, CO_2 gas, and welding current are fed.

This gun will operate with welding currents up to 320 A., and has been carefully designed to eliminate operator fatigue. It is claimed that the balance in the hand is excellent, and that the "press-to-start, press-to-stop," trigger switch removes finger strain. The weight in the hand is only 3¼ lb., with feed cable attached. A heat barrier is incorporated in the body of the gun, and a heat-proof hand shield is fitted. The feed cable is composite and includes, in addition to a tube which carries the welding wire and CO_2 gas, the switch and welding current leads. Cable length is 12 ft., and the machine head rotates through 180° on a turntable, permitting up to 20 ft. of horizontal welding gun movement to be made without check.

Mounted on the turntable are the wire coil holder, and the wire feed mechanism and its drive motor and speed controls. Three sizes of wire, 0·9, 1·2, and 1·6 mm., can be used, and it is only necessary to change the gun contact tip when changing wire size. The coil holder takes 44 or 56 lb. coils, and has an automatic friction brake. During welding the wire is fed by a solenoid-operated pressure roll and is automatically straightened by an adjustable arrangement of rollers. Wire speed is continuously variable between 6 and 54 ft./min. by means of a graduated control accessibly mounted on the gear box. Two standard CO_2 gas cylinders are carried in racks, fixed one on each long side of the unit. CO_2 heater, gas regulator gauges and flow cartridge are fully protected within the body.

The control panel carries voltmeter and ammeter, both protected by a robust plastic visor, together with on/off switch, fuses, and a red warning light, which glows if any of the inter-locking safety controls operate. These safety interlocks automatically cut off the welding current and stop the wire feed if the gas supply fails. When the welding current is supplied from a motor-generator, an additional automatic control relay only allows the wire feed to operate when the generator field voltage has reached the correct value. The unit is suitable for either rectifier or motor-generator operation.

Research and Control Instruments, Ltd., Instrument House, 107 *King's Cross Road, London, W.C.*1.

Airless Spray Painting Plant

LARGE products that cannot be placed in spray booths can be spray painted on the shop floor with considerable reduction in paint fog and rebound with the Aerograph-DeVilbiss airless spray painting plant, which will spray a very wide range of materials by fluid pressure alone, without atomisation air, heat or multiple hose lines. As it will spray paints at very high viscosities which the conventional compressed air operated spray gun has difficulty in handling, a thick film can be built up for good protection with few coats.

The plant consists of 24 : 1 ratio pump mounted on a pneumatic-tyred hand truck which is fitted with a paint agitator, air lift, air pressure regulator and a 10 gal. container (into which a 5 gal. paint drum may be placed); a heavy duty spray gun with tungsten carbide spray cap; stainless steel wire braid reinforced high-pressure material hose; and a heavy duty air supply hose. The air motor driven agitator mixes the paint and keeps it in proper suspension and the air lift allows paint containers to be changed over rapidly and easily. The air pressure regulator controls material pressure for ideal atomisation and the tungsten carbide spray caps that are available will handle a wide variety of paints at varying viscosities and fluid flows.

The Aerograph-DeVilbiss Co. Ltd., 47, *Holborn Viaduct, London, E.C.*1

CURRENT LITERATURE

Book Notices

DATA SHEETS ON DUST COLLECTORS

10 × 8 in., paper covers, ix + 35 pp. Published by the British Steel Castings Research Association. 30s. postage paid.

EQUIPMENT for the collection of industrial dusts and fumes has attracted considerable attention, particularly since the passing of the Clean Air Act, the implementation of which will in numerous cases involve the purchase, installation, and regular maintenance of such equipment, not merely by makers of steel castings, but also by many organisations engaged in other sectors of industry.

Many different types of dust collectors have been introduced to the market under various trade names in recent years, making it increasingly difficult for potential users of such equipment to keep abreast of developments in this specialised field. In order to facilitate the selection of the most suitable unit for a particular purpose, the British Steel Castings Research Association broke new ground by compiling a series of data sheets, giving up-to-date details of specific dust collectors suited primarily to steel foundry applications. A book containing these data sheets was first published in May, 1958, in an edition limited to members of B.S.C.R.A. The Association has now decided to make this book generally available in a second (revised and enlarged) edition. The data sheets included in this book contain details of thirty-two dust collectors made by nineteen organisations, and as far as possible the collection efficiency, pressure drop, and water usage of each type of collector are clearly indicated. A diagram, showing the principle of operation, is given in each case.

An introduction, containing comments on types, selection, location and the approximate cost of dust collectors, as well as a table of efficiency curves for each type of collector, are also included in this new B.S.C.R.A. book, the timely appearance of which will, it is hoped, be of value to many organisations.

MOLYBDENUM METAL

Copies available free on application to Climax Molybdenum Co., of Europe, Ltd., 2, Cavendish Place, London, W.1.

THIS publication is almost wholly concerned with unalloyed molybdenum metal. Molybdenum is one of sixteen industrial non-ferrous metals used in substantial quantities in the pure state. Present applications indicate that the properties of this metal are of ever increasing importance: high melting point; high modulus of elasticity; high strength at elevated temperatures; high thermal conductivity; high resistance to corrosion; low specific heat; and low coefficient of expansion. These exceptional properties first made molybdenum extremely useful in the incandescent lamp industry, and more recently in the electronics field. Originally produced by the powder metallurgy method, increasing demand led to the development of better processing methods and to its production by arc casting. The properties of molybdenum which are retained at moderately high temperatures are strength, toughness, and resistance to repeated shocks. In the annealed state molybdenum can be drawn, stamped, folded, hammered, woven, etched, engraved, or machined. Its widening industrial use has led to increased production facilities, new fabrication methods, and improved quality of product.

This booklet not only gives information concerning the many applications of molybdenum in incandescent and fluorescent lamps, electronic tubes, electric furnaces, electrical contacts and electrodes, brushes, miniature dry cells, miniature electric transducers, and transistors and rectifiers; its outstanding properties have also led to its increasing application in more recent engineering developments, to which much valuable information is allocated. Thus, for instance, the missile and aircraft industries, metal working industry, nuclear-energy industry, chemical industry, glass industry, and the metallising industry. In addition to the foregoing, molybdenum has found many miscellaneous uses: for instance, high temperature springs, thermocouples, gas ports for rapid-fire cannons, bimetal fire detectors, and assorted laboratory equipment. Among the latter mention may be made of cells for high-temperature research, high-temperature length standards, crucibles for experimental melts, crucibles or cathodes for high-temperature electrolysis, rods to support aircraft in wind tunnels and grips for high-temperature tensile testing. Molybdenum, in powder form, has also shown promising results as a filler in polytetrafluoroethylene bearings.

The major part of this booklet is devoted to a review of the known engineering data concerning molybdenum metal; its physical and mechanical properties; resistance to corrosion; resistance to and protection from oxidation; fabrication of parts; methods of production; laboratory techniques. In addition are weight tables and about 10½ pages of references to literature on the subject.

Trade Publications

AIDS to metallography, ranging from bench polishing machines, through polishing cloths and polishing powders, to Diaplast diamond polishing compound, are featured in a leaflet and price list available from Metallurgical Services, Reliant Works, Betchworth, Surrey.

AT the Fort Saskatchewan, Alberta, Canada, refinery of Sherritt Gordon Mines, Ltd., nickel, cobalt, copper and composite powders are produced. A booklet describing these powders and their production—based on ammoniacal leaching of concentrates followed by precipitation by hydrogen—is available from the company.

FEATURED in *Foseco Foundry Practice*, No. 140, is an investigation of a defective grey iron grooved pulley, an account of the use of die dressings in pressure die casting, and a note on shrinkage porosity.

THE abstracts comprising the July issue of *The Nickel Bulletin* illustrate the wide range of industries and applications in which nickel plays an important role. In the section on nickel and its compounds reference is made, for example, to literature on the reactions involved in porcelain enamelling, and on the use of nickel in cathodes. Items pertaining to electrodeposition are followed by sections on non-ferrous alloys (e.g. arc

welding of aluminium bronze using nickel-containing filler metal) and the properties and applications of nickel-iron magnetic alloys. In the section concerned with heat and corrosion-resisting materials the literature abstracted ranges in content from service experience with Nimonic 80A turbine blades and the properties of a nickel/mullite high-temperature bearing cermet, to the production and properties of sintered stainless-steel parts, the resistance of nickel-containing steels and alloys to corrosion, and an assessment of the suitability of nickel-containing materials for nuclear reactors. The issue contains the usual quarterly survey of recent patent literature.

We have received from Magnesium Elektron, Ltd., a general table of mechanical properties and chemical compositions of magnesium alloys. These are divided into cast and wrought types and the properties given cover tensile, compression, fatigue, impact and hardness testing.

A new leaflet from C. & P. Development Co. (London), Ltd., describes their Rust-Anode zinc-rich paint. This is a metal coat applied to steel surfaces by brushing, spraying or dipping. It leaves a coat claimed to be pure zinc and strongly adherent, ageproof and rustproof.

"Hydraulic Oils" is the title of a 74 page handbook just published by Wakefield-Dick Industrial Oils, Ltd., a member of the Castrol group of companies. This book, which contains 50 illustrations, includes chapters on fundamental hydraulic principles; hydraulic systems, pumps and components; and hydraulic fluids.

The production of prefabricated components for the Brockhouse patent system of steel construction is described in the July/September issue of *The Forge*. Another article deals with the torque convertor as an aid to transmission performance, and from overseas there is a report on the use of cold rolled sections, made by a subsidiary company in Canada for a special panel system employed in dam building.

"New, Neat and Nippy" is the title of an article in *I.C.I. Pretreatment*, No. 23, describing the Folland all-aluminium speedboat, which is given extra resistance to corrosive marine atmospheres by the use of I.C.I. Alocrom. Other articles in this issue are concerned with the use of I.C.I. Granodine as a protection against corrosion and rust creep in Scammell heavy duty lorries and Shay powered gardening tools.

Publication No. 2023 takes the form of an article showing how Kent instruments and automatic control are applied to reheating furnaces. Four schemes are described; the first two, alternative systems for a small single-zone furnace; the third for multi-zone furnaces; and the fourth for the protection of metallic recuperators against excessive temperatures.

Gas-carburising furnaces using Incoloy DS, nickel-chromium-iron alloy, for the retort containing the carbon rich atmosphere is the subject of an illustrated article in the latest edition of *Wiggin Nickel Alloys*. Further articles included, deal with the use of Nimonic 90 heat-resisting alloy in the "hot-zone" of a high temperature extensometer built for the R.A.E.; mechanical seals for pumps and other equipment used in the chemical industry in Monel corrosion-resistant alloys; details of research work which has gone into improved alloys for spark plug electrodes and descriptions of many types of solenoid valves using Nilo 48 controlled-expansion alloy for the magnetic components. The publication is free on request from the Publicity Department, Henry Wiggin & Co., Ltd.

We have received from Negretti and Zambra, Ltd., copies of publications T48, R/42, R/43, H23, and R30 RU, dealing, respectively, with general purpose Mersteel rigid stem dial thermometers; Gas-Stat indicating and recording controllers; electrical contact indicating and recording controllers; Gregory type electrolytic differential humidity indicators; and air-operated control regulating units.

For some time now all the rolling mill pinions produced at the Darnall works of Davy and United Engineering Co., Ltd., have been case-hardened in an EFCO gas carburising plant, this procedure superseding an arrangement whereby the larger pinions were made in the U.S.A. As the maximum size of pinion is 36 in. diameter by 72 in. long, with a weight of 5 tons, the plant for heat treating them is not without interest, and for this, readers are referred to the August, 1960 issue of *EFCO Journal*. A second article traces briefly the development of materials which man has used for writing upon, from clay tablets to modern paper, and the machines for making it, and makes reference to the use of bright annealing in making the "wire"—an endless woven wire belt. Other features include a description of the first installation in this country for vacuum annealing copper wire and advice on getting the most out of an exothermic generator.

Books Received

"Third Metallurgy Symposium on Corrosion" (Saclay 1959). 239 pp. France and Amsterdam, 1960. Centre D'Etudes Nucleaires de Saclay and North Holland Publishing Company. 72s.

"Radiation Pyrometry and its Underlying Principles of Radiant Heat Transfer." By T. R. Harrison. 234 pp. New York and London, 1960. John Wiley & Sons, Inc., and Chapman & Hall, Ltd. 96s. net.

"Atomic Theory for Students of Metallurgy." By W. Hume-Rothery. Third (revised) edition. 427 pp. inc. name and subject indexes. London, 1960. Institute of Metals. 50s. ($7·50).

"A Manual of Foundry Practice for Cast Iron." By J. Laing and R. T. Rolfe. Third Edition revised and enlarged by R. T. Rolfe. 386 pp. inc. index and numerous illustrations. London, 1960. Chapman & Hall, Ltd. 50s. net.

"Structure and Change: An Introduction to the Science of Matter." By G. S. Christiansen and P. H. Garrett. 608 pp. 487 drawings by E. Gillespie—many in two colours. San Francisco and London, 1960. W. H. Freeman and Co., Ltd. 63s.

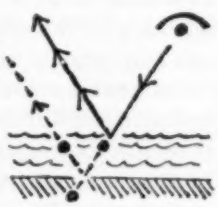
"Werkstoffe für elektrische Kontakte." By A. Keil. 347 pp. inc. name and subject indexes and numerous illustrations. Berlin/Göttingen/Heidelberg, 1960. Springer-Verlag. Ganzleinen DM48.

"Progress in Metallurgical Technology." (Lectures delivered at the Institution of Metallurgists Refresher Course, 1959). 147 pp. inc. index. London, 1960. Iliffe & Sons, Ltd. 32s. 6d. net.

Infra-Red Heating

Infra-red heating is the name given to the method of using in industrial processes radiant heat from heaters specifically designed for that purpose. This differentiates it from methods employing both radiation and convection, as in furnaces, although the effect of the radiation is much the same in both cases.

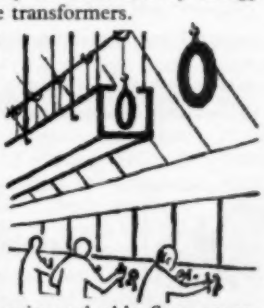
Radiant heat provides a higher rate of heat transfer to bodies not highly reflective than does convection, unless high-velocity forced convection is used. The rate of heating of a body depends upon the intensity of radiation on its surface, the proportion absorbed by the surface and, subsequently, on heat conduction. In heating very thin bodies, for example paint films, the radiation not reflected nor absorbed passes through and is in turn reflected or absorbed by the underlying material. This reflected heat is partly absorbed by the paint film "on the way back". Despite this effect it is an exaggeration to claim that infra-red "heats from the inside out" and it remains largely a surface heating effect except in a few special cases.



Infra-red heaters mainly use metal-sheathed elements in special reflectors, but infra-red lamps with internal reflectors are still used in special cases. Other types use silica-sheathed elements or quartz-sheathed lamps in reflectors. A wide range of heaters is available with simple mounting arrangements to enable heat to be applied quickly and effectively either in a production line or in some odd corner.

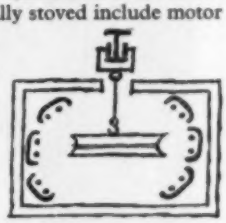
Control of the charge temperature is effected by regulating the heating time and power. In the case of a moving charge, this is done by adjusting the conveyor speed and the number of heaters in circuit, i.e., by adjusting the effective length of the oven. Some of the heaters may be controlled by energy regulators or adjustable transformers.

The advantages of infra-red heating over convection heating include reduced heating times, reduced floor space, lower installation costs, almost instant starting, ability to focus the heat, and flexibility in effective oven length. Infra-red ovens can often be mounted in the roof, saving valuable floor space. Infra-red heating is not generally favourable for heating large bodies of low heat conductivity.



Paint Stoving

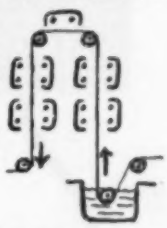
Not all paints are suited to infra-red radiation, but suitable paints are stoved quickly and often give a better finish. Synthetic enamels are the most suitable. Articles successfully stoved include motor car bodies, wheels and other accessories, refrigerator and washing machine cabinets, cylindrical drums and barrels, metal furniture, valve hand wheels, metal toys and a host of other articles. Lacquers and varnishes are being quickly and effectively stoved on jewellery, packing strips, tubes, films and similar products. Special infra-red lamp ovens stove synthetic finishes on wooden furniture and components. In all cases stoving times have been reduced very considerably.



Moisture Extraction

Sheathed element heaters are particularly useful for drying surface water films, their radiation being readily absorbed by water. High rates of drying are possible provided the water vapour can readily disperse. Drying of "contained" water can be effected provided the water can diffuse from the interior at a rate equalling the surface drying rate. With heat-sensitive materials sheathed element heaters may have to be arranged to move away from the material to avoid overheating if the conveyor stops, being interlocked with the conveyor for this purpose. Lamps are sometimes used instead for such materials because of their instantaneous cut-off.

Infra-red is widely used for drying coatings and inks on paper and textile products, bottle seals and labels, clayware and glazes, pigments on leather and many other products.



Plastic Heating

Infra-red heating is widely used in the plastics and allied industries. Typical applications are the preheating of plastic pellets and of sheets prior to moulding, curing of plastic and rubber sheets and belts, heat setting of nylon and similar fabrics, drying and curing of latex films on carpets and many others where a plastic forms the whole or part of the product.

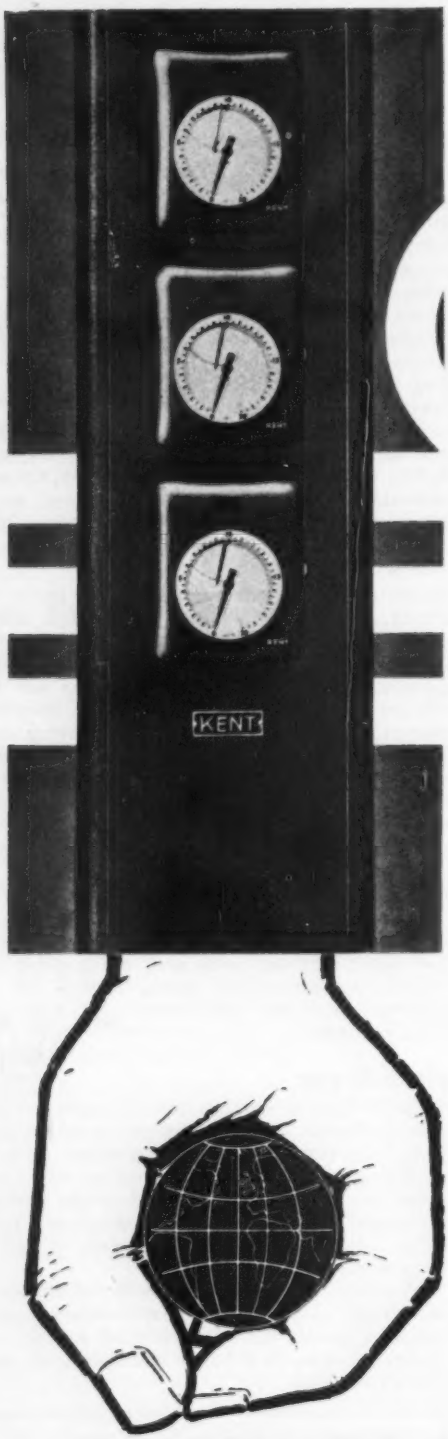
The above are just a few examples of successful applications of infra-red. In many other processes infra-red heaters can often be fitted quickly and cheaply, to save time, labour and floor space and, therefore, money.

For further information, get in touch with your Electricity Board or write direct to the Electrical Development Association, 2 Savoy Hill, London W.C.2. Telephone: TEMple Bar 9434.

Excellent reference books on electricity and productivity (8/6 each, or 9/- post free) are available — "Resistance Heating" is an example; "Induction and Dielectric Heating" is another.

E.D.A. also have available on free loan in the United Kingdom a series of films on the industrial uses of electricity. Ask for a catalogue.

CUT HERE



Single-unit panel mounting
Commander KE electronic temperature
indicator/recorder/controllers

Commanders in control

East and west, in a host of process industries and services, the versatile—still-expanding—KENT *Commander* range of instruments is contributing towards efficient measurement with all the user-advantages of component interchangeability, rationalization and minimum maintenance. Indicators, circular-chart recorders, pneumatic transmitters, automatic controllers (single-, two- or three-term), receivers, receiver-controllers ; temperature, rate of flow, pressure, oxygen-percentage, level, specific gravity . . . the list of variants and variables is too long to detail here. Among the new models on the way are those for open-channel flow and low-head differential pressure.

Controlling Units

Commander controllers incorporate one of the *Mark* 30 Series of air-operated units (transmission available as an alternative), providing proportional ; proportional and integral ; proportional and derivative ; or proportional, integral and derivative control actions.

Brochures illustrating and describing any group of instruments in the *Commander* range will gladly be sent on application. Write or telephone Metallurgical Contracts Dept. (Luton 2440) for a quotation.

masters of instrumentation

GEORGE KENT LIMITED · LUTON · BEDFORDSHIRE · ENGLAND

Telephone: Luton 2440 Cables and Telegrams: Kents Luton Telex

Registered Office: 199-201 High Holborn, London, W.C.1
Factories, Subsidiary Companies, Branch Offices, and Representatives throughout the world.

LABORATORY METHODS
MECHANICAL · CHEMICAL · PHYSICAL · METALLOGRAPHIC
INSTRUMENTS AND MATERIALS
OCTOBER, 1960 Vol. LXII, No. 372

The Determination of Small Amounts of Cobalt in Highly Alloyed Metals

By R. C. Rooney, A.R.I.C., A.C.T.Birm.
The British Cast Iron Research Association

The method previously described for the determination of small amounts of cobalt in cast iron and steel has been applied to a wide range of highly alloyed materials, ferroalloys, etc. Possible interferences have been investigated, and a procedure developed which prevents the interference of all of the common metals.

A RAPID method for the determination of cobalt in plain cast iron and steel has been previously described,[1] by which cobalt contents in the range 0·0005–0·3% can be determined in about an hour. Since this work was completed, it has become necessary to determine cobalt at similar levels in highly alloyed materials and in various ferroalloys, furnace additives, inoculants, etc. Application of this rapid method to such materials has therefore been investigated.

EXPERIMENTAL WORK

Interfering Elements

As a preliminary to the investigation of the behaviour of highly alloyed materials in the analytical procedure, the behaviour of a number of elements in the spectrophotometric determination of cobalt with 2-nitroso-1-naphthol was examined. According to Boyland,[2] the only interference encountered in the *p*H range 4–9 was from iron, nickel, copper, tin, silver, bismuth and chromium. In the present author's earlier work, no chromium complex was noted at *p*H 5; tin, silver and bismuth were not investigated. Boyland's report that up to 3 mg. of all the metal complexes, except that of cobalt, were destroyed by shaking with 10 N hydrochloric acid was confirmed.

Claasen and Daamen[3] used a citrate buffered solution at *p*H 5, and reported no interference from a large number of elements, including ferric iron, tin, bismuth and chromium, and greatly diminished interference from nickel. More than about 25 mg. of copper caused low results, however, and the presence of citrate made it necessary to stand the solution for at least 30 minutes before extracting the cobalt complex. These workers used chloroform as extractant, in order to avoid the use of inflammable solvents; the procedure described below uses benzene, as it is considered that the convenience of carrying out the extraction and washing of the extract in a single separating funnel outweighs the hazards of inflammability and toxicity. Due precautions against these hazards should be taken; chloroform can be substituted if required, with no alteration to the chemical procedure and due modification of the extraction process.

TABLE I—BEHAVIOUR OF VARIOUS ELEMENTS WITH 2-NITROSO-1-NAPHTHOL AT *p*H5 (1·0 mg. of each element used in a solution volume of 50 ml., buffered to *p*H5. 5 ml. of 1% reagent in acetone added to each).

Result	Element	Colour of Precipitate
No precipitate formed	Alkali metals, alkaline earth metals, beryllium, magnesium, aluminium, rare earth metals (cerium and lanthanum tested), titanium,* zirconium,* thorium,* vanadium, niobium,* tantalum,* chromium (hexavalent), molybdenum, tungsten,* uranium, manganese, platinum, rhodium, zinc, cadmium, indium, thallium, germanium, tin (tetravalent), lead, arsenic (pentavalent), antimony (pentavalent), bismuth, selenium and tellurium.	
Precipitate formed	Nickel	Orange-red
	Mercury	Dark red
	Silver	Dark orange-red
	Iron (trivalent)	Green
	Copper (divalent)	Orange-red
	Chromium (trivalent)	Reddish brown†
	Cobalt	Red

* Hydrofluoric acid added to these elements to prevent hydrolysis, and reagent added before *p*H buffer.
† Formed only occasionally.

In the absence of further information regarding interfering elements in non-complexing solutions, it was decided that a more extensive survey should be made. The elements investigated, together with their behaviour under the conditions employed in the analytical procedure, i.e. an acetate buffered solution of *p*H 5–5·5, are shown in Table I.

It is apparent that of the elements investigated, only nickel, mercury, silver, iron, copper and chromium will interfere. The effect of 10 N hydrochloric acid on these complexes was investigated at concentrations up to 100 mg. It was found that the complexes due to 100 mg. of nickel, chromium, silver and mercury were completely destroyed by shaking for 10–15 seconds with 10 ml. of 10 N hydrochloric acid.

Copper and iron were found to react rather differently. These elements form complexes which are not very easy to destroy with 10 N hydrochloric acid; when the complex from 5 mg. of the metal was formed at *p*H 5, extracted into benzene, and shaken with acid, 1–2

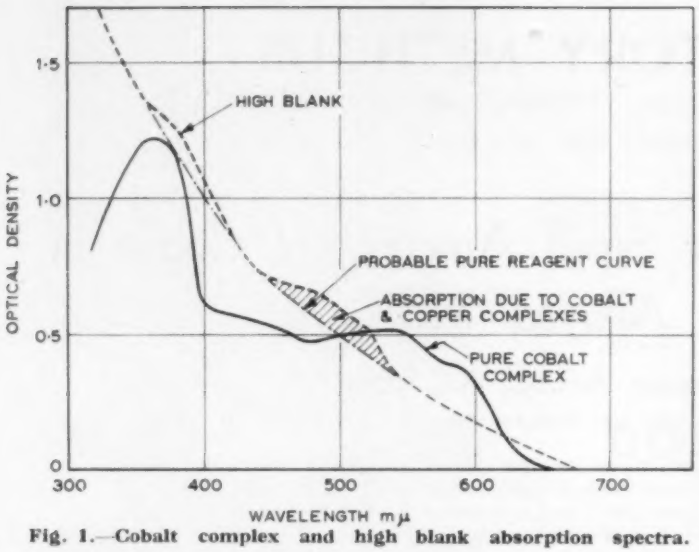


Fig. 1.—Cobalt complex and high blank absorption spectra.

minutes shaking was required in order to destroy the complex completely. Above 5 mg. the shaking time required became longer and at the 100 mg. level several acid washes were required, with intermediate alkali washes to remove the liberated reagent.

The behaviour of trivalent chromium was unusual in that no precipitate was formed at low chromium concentrations, but at the 100 mg. level a precipitate was found to form slowly on some occasions. On others, standing for as long as 30 minutes had no effect and no precipitate was obtained. As the cobalt complex forms rapidly, only small amounts of reagent were needed as the cobalt complex was completely formed before competition for the reagent occurred from the chromium. It is considered likely that this behaviour of chromium is due to the chromium being present sometimes as the green and sometimes as the violet ionisation isomer.

It is apparent that the only serious interference, in the elements studied, is from large amounts of copper and iron. These elements can be completely removed by extraction with chloroform and cupferron from acid solution as in the method previously described, and this extraction will also remove many other elements. Although most of these elements, such as vanadium or molybdenum, will not interfere, the removal of titanium, thorium, zirconium, etc., is advantageous in that it prevents losses by adsorption on to the precipitated hydroxides of these elements, which would tend to hydrolyse at *p*H 5.

Of the interfering elements remaining in solution after the cupferron extraction, nickel and chromium are by far the most important in ferrous materials, and attention was paid to the separation of cobalt from these elements.

Separation of Cobalt from Nickel

It was shown in the earlier work that 1 mg. of nickel plus cobalt requires about 3·5 mg. of 2-nitroso-1-naphthol for complete complex formation, and 10 ml. of a nearly saturated (0·1%) solution in methanol was used. This called for unwieldy volumes of reagent solution in order to cope with 100 mg. of nickel, so that a 1% solution in acetone was substituted. 10 ml. of this solution is sufficient for 30 mg. of nickel.

When more than 10 mg. of nickel was present, it was found that the extraction was rendered difficult because of the low solubility of the nickel complex in benzene. This was overcome by adding the reagent to the solution in a volume of 40–50 ml. buffered to *p*H 5, and allowing the complex to form. 20 ml. of 10 N hydrochloric acid was then added, when the nickel complex dissolved almost completely. The small amount of nickel complex remaining, together with the cobalt, was then extracted into benzene with 10 N hydrochloric acid as before.

When more than 50 mg. of nickel was present, necessitating the use of more than 20 ml. of the 1% reagent solution, some difficulty was encountered in the extraction. After the acid wash, the water wash caused the formation of a bulky precipitate of water-insoluble naphthol hydrochloride. This obscured the interface, caused entrainment of the benzene phase in the aqueous phase and occasionally caused complete emulsification. The addition of a second 10 N hydrochloric acid wash removed sufficient naphthol to overcome this difficulty. Above 100 mg. of nickel, however, the extraction became very difficult.

It was noted that with 1% reagent solution, high blanks were obtained which were directly related to the amount of reagent used. This was at first attributed to cobalt in the reagent, but when larger amounts of reagent were used it was seen that the blank solutions were brown; wet oxidation of the organic phase, followed by polarographic examination, revealed the presence of only small amounts of cobalt and no nickel.

An absorption spectrum of a high blank solution was plotted and is shown compared with that of the cobalt complex in Fig. 1. There is a small superimposed peak at 500–550 mμ, which is probably due to cobalt and copper, but most of the absorption is due to the background spectrum. This appears to be due to some coloured impurity in the reagent which is not removed by acid or alkali washing. The blank solution was evaporated to dryness and all the benzene removed under vacuum. A dark brown residue, amounting to about 0·2% of the naphthol, remained. This residue was examined spectrographically and was found to contain only very small amounts of copper and cobalt, being almost entirely organic. Infra-red spectrophotometry showed it to be entirely aliphatic in nature, proving the complete removal of the excess naphthol; the residue appeared to be composed mainly of long, branched-chain aldehydic compounds.

Recrystallisation of the reagent from hot water, as recommended by Boyland, failed to remove the blank and the reagent was purified by dissolving in hot sodium hydroxide solution, filtering and re-precipitating the naphthol by the addition of a slight excess of hydrochloric acid.

When freshly prepared, this purified reagent gave satisfactory blanks at 530 mμ when volumes of 1% solution up to 40 ml. were used. The blanks at 365 mμ were still high and erratic, so that this wavelength could not be used. On keeping the solution for 24 hours,

coloured blank solutions were again obtained, although this time they were less strongly coloured, and clear yellow. With old reagent, 10 ml. is the maximum amount that should be used. The results obtained when cobalt was added to nickel chloride solutions are shown in Table II.

These results are considered satisfactory. If the blanks from the 50 and 100 mg. samples are considered, the nickel chloride used can be shown to have a cobalt content of approximately 5 p.p.m. The addition of 1 μg. of cobalt to 100 mg. of nickel showed a recovery of 1·1 μg., in spite of a blank level of 3 μg.

It is seen that 1 μg. of cobalt can be determined in 100 mg. of nickel, provided that the reagent is freshly purified. For routine use, however, it is better to limit the nickel content to about 30 mg. so that only 10 ml. of reagent is required ; this will keep the blank reading low, while still permitting the use of reagent purified in batches of an economical size.

Separation of Cobalt from Chromium

The erratic behaviour of chromium^{III} was considered to be a disadvantage, and attempts were made to overcome this by oxidising the chromium to chromium.^{VI} This was satisfactory in that no precipitate formed, but experiments with cobalt/chromium mixtures showed that low cobalt recoveries were obtained when 10 μg. of cobalt was added to more than 50 mg. of chromium.^{VI} Only small amounts of reagent were added, and it is possible that some oxidation of the reagent occurred. The use of larger amounts of reagent gave coloured blank solutions, even when using purified reagent. When the chromium was reduced to the trivalent state, no such loss of cobalt occurred, even when a chromium complex precipitated. The recovery of cobalt from chromium^{III} solutions is shown in Table III.

Solution Techniques

The range of materials to be examined was such that some attention was paid to the methods to be used to dissolve them. It was considered an advantage to use a solvent which would be as widely applicable as possible. The requirements for the solvent are that the final solution shall be at least 3 N in acid, so that there is sufficient acid reserve to keep the *p*H below 1 during the cupferron extraction ; that the acid should be volatile so that fuming with perchloric acid gives a reproducible acidity ; and that the acid itself should not interfere with the cupferron extraction.

It was found that with the exception of ferroniobium, ferrotitanium, ferrosilicon, ferrotungsten, 14% silicon iron, iron ore and nickel shot, all the materials dissolved quite readily in aqua regia. The addition of hydrofluoric acid to the aqua regia dissolved the ferroalloys ; hydrochloric acid with a little stannous chloride dissolved the iron ore and was followed by oxidation with nitric acid ; and concentrated nitric acid dissolved the nickel shot more readily than had aqua regia. Large amounts of silica were precipitated when ferrosilicon and 14% silicon iron solutions were evaporated to fumes with perchloric acid, so that the usual B.C.I.R.A. ferrosilicon solution technique was used. This consists of dissolving 1 g. of sample in 15 ml. of warm nitric acid by the cautious addition of hydrofluoric acid and evaporating to dryness in a platinum basin. A radiation bath as described by Westwood and Mayer[4] is useful for this evaporation. The residue is then dissolved by warming gently with 30 ml. of hydrochloric acid and then treated as an unalloyed sample.

TABLE II.—RECOVERY OF COBALT FROM NICKEL

Nickel Present (mg.)	Cobalt Present (μg.)	Amount of 1% Reagent (ml.)	Cobalt Found (μg.)
5	0	2·0	0·5, 0·5
5	10	2·0	11, 11
10	0	5·0	0·8, 0·8
10	10	5·0	12, 11
25	0	10	1·0, 1·1
25	10	10	11, 11
50	0	20	1·9, 1·9
50	10	20	12, 12
100	0	40	3·1, 3·2
100	1	40	4·2, 4·3
100	10	40	13, 14

No difficulty in the cupferron extraction was encountered due to the presence of fluoride. The removal of iron is virtually complete, but some titanium, vanadium, tungsten and niobium remain in solution. Insufficient remains, however, to cause any difficulty in the 2-nitroso-1-naphthol extraction.

Application to Various Materials

A range of materials has been analysed by the projected procedure ; most of these samples are not standardised for cobalt, and reproducibility alone in such cases cannot be considered sufficient evidence that the results are, in fact, accurate. The ferroalloys and other materials used as the first thirteen samples are some of those analysed by the B.I.S.R.A. Methods of Analysis Committee by the method described by them.[5] The cobalt contents shown for these samples are the B.I.S.R.A figures and are the ranges of figures from eleven different co-operating laboratories. The agreement shown between the two independent methods, together with the evidence presented above with regard to interfering elements, cobalt recovery, etc., plus the consistency of the results obtained, is regarded as strong evidence that the results are, in fact, accurate.

It is considered probable that the procedure described should be applicable to a much wider range of materials ; the requirements are that the total content of metals removed by cupferron should not exceed 100–200 mg., that the nickel plus silver and mercury content should not exceed a further 30 mg. (or 100 mg. if freshly purified reagent is used) and that the acidity requirements in the original solution referred to above can be adhered to.

The results on the highly alloyed and other materials analysed are shown in Table IV.

RECOMMENDED PROCEDURE

Reagents

Very little trouble with reagent blanks has been experienced in the determination of cobalt at the 1 μg. level. It is recommended that reagents should be of AnalaR or equivalent grade whenever possible.

Hydrochloric Acid (s.g. 1·16).

Nitric Acid (s.g. 1·42).

TABLE III.—RECOVERY OF COBALT FROM CHROMIUM

Trivalent Chromium Present (mg.)	Cobalt Added (μg.)	Cobalt Found (μg.)
100	1	1·1, 1·3
100	10	9·9, 10·2
100	100	98, 100
100	250	246, 252

1·0 ml. of 1% reagent solution added in all cases.

TABLE IV.—RESULTS OBTAINED ON A WIDE RANGE OF MATERIALS

Sample	Cobalt Content (%)	Amount of 1% Reagent Used (ml.)	Cobalt Found (%)	Remarks
Ferromanganese—M.G.S. 283 (76–78% Mn) ..	0·023–0·026	1·0	0·023, 0·023, 0·025	$NH_2OH.HCl$ added after fuming to redissolve MnO_2.
Ferrochromium—M.G.S. 321 (70% Cr)	0·043–0·047	1·0	0·047, 0·048, 0·049	Hexavalent chromium reduced after fuming.
Ferroniobium—M.G.S. 328 (Nb content not quoted. 50–60% ?)	0·002–0·003	1·0	0·0029, 0·0032, 0·0030	Dissolved in aqua regia/HF.
Ferrotitanium—M.G.S. 329 (38–39% Ti) ..	0·017–0·020	1·0	0·020, 0·020, 0·020	Dissolved in aqua regia/HF.
Carbon Steel—M.G.S. 64	0·010–0·012	1·0	0·012, 0·012, 0·013	
Chromium Steel—M.G.S. 182 (20% Cr)	0·025–0·027	1·0	0·025, 0·026, 0·025, 0·026,* 0·025*	Chromium reduced.
Mild Steel—B.C.S. 271	0·011–0·014	1·0	0·015, 0·013, 0·013	Previous, 0·015, 0·015, 0·013.
Mild Steel—B.C.S. 273	0·019–0·023	1·0	0·021, 0·021, 0·021	Previous, 0·021, 0·022, 0·023.
Mild Steel—B.C.S. 276	0·024–0·026	1·0	0·024, 0·026, 0·026	Previous, 0·026, 0·025, 0·025.
Low Alloy Steel—M.G.S. 310 (4% Ni, 0·5% V)	0·037–0·042	2·0	0·043, 0·042, 0·041	
Low Alloy Steel—M.G.S. 311 (2% Cr, 0·3% V)	0·029–0·032	1·0	0·032, 0·033, 0·030	
Swedish Iron—M.G.S. 304..	0·003–0·0035	1·0	0·0026, 0·0030, 0·0027	
Stainless Steel—M.G.S. 305 (18% Cr, 8% Ni)	0·0025–0·004	3·0	0·0030, 0·0030, 0·0029	Chromium reduced and HCl added before cobalt extracted.
Stanton Pig Iron	—	1·0	0·015, 0·015, 0·014	
Bradley & Foster Pig Iron	—	1·0	0·025, 0·025, 0·025	
Gjers Mills Hematite Iron	—	1·0	0·0069, 0·0066, 0·0069	
Valley Cold Blast Pig Iron	—	1·0	0·018, 0·018, 0·017	
Ferrosilicon (80% Si)	—	1·0	0·0058, 0·0057, 0·0056	Dissolved HNO_3/HF.
14% Silicon Iron	—	1·0	0·012, 0·013, 0·012	Dissolved HNO_3/HF.
Ferromolybdenum (73% Mo)	—	1·0	0·011, 0·011, 0·011	
Ferrovanadium—B.C.S. 205 (52% V)	—	1·0	0·0055, 0·0055, 0·0057	
Ferrotungsten—B.C.S. 202 (81% W)	—	1·0	0·055, 0·053, 0·056	Dissolved aqua regia/HF. Some WO_3 precipitated after fuming.
Ni-Resist (16% Ni, 3% Cr, 7% Cu, 1% Mn) ..	—	6·0	0·048, 0·049, 0·049	HCl added before cobalt extracted.
Chromium Iron—(30% Cr)	—	1·0	0·025, 0·028, 0·030, 0·028,* 0·029*	Chromium reduced.
Nomag (11% Ni, 7% Mn)	—	4·0	0·015, 0·015, 0·015	HCl added before cobalt extracted.
Low Alloy Cast Iron B.C.S. 172/2 (2% Ni, 1% Mn, 0·5% Cr, 0·4% Mo)	—	1·0	0·014, 0·014, 0·014	HCl added before cobalt extracted.
Nodular Iron (1·5% Ni, 0·1% Mg)..	—	1·0	0·023, 0·023, 0·023	HCl added before cobalt extracted.
Iron Ore—B.C.S. "A" (58% FeO, 8% SiO_2, 2% CaO, 1% MgO)..	—	1·0	0·0024, 0·0024, 0·0024	Dissolved HCl/$SnCl_2$/HF and oxidised with HNO_3.
Mischmetall (45% Ce, 50–55% other rare earths)	—	1·0	0·0003, 0·0004, 0·0003†	
Nickel-Magnesium Alloy (85% Ni, 12% Mg, 3% Fe)	—	30	<0·0005, <0·0005, <0·0005	HCl added before cobalt extracted. No cupferron extraction. 2 HCl washes of benzene layer.
Nickel Shot (98—100% Ni)	—	40	<0·0005, <0·0005, <0·0005	

* Cr volatilised as CrO_2Cl_2
† 0·5 g. sample, no cupferron extraction.

Perchloric Acid (s.g. 1·54 (60%)).

Hydrofluoric Acid (40%).

Cupferron (6%)—Dissolve 6 g. of cupferron in water and dilute to 100 ml. Filter before use. This solution must be made up freshly as required.

Sodium Acetate (2 M)—Dissolve 272 g. of hydrated sodium acetate ($CH_3COONa.3H_2O$), in water and dilute to 1 litre.

Sodium Hydroxide (1 N)—Dissolve 40 g. of sodium hydroxide pellets in water and dilute to 1 litre. Store in a polythene bottle.

2-*Nitroso*-1-*Naphthol* (1%)—Dissolve 7·5 g. in 300 ml. of 10% sodium hydroxide and heat to boiling. Filter on a No. 541 paper, washing with hot water. Cool the filtrate and add hydrochloric acid until just acid, and add 2 ml. in excess. Cool, filter and wash with cold water. Press dry on filter paper and dissolve 5 g. in 500 ml. of acetone.

Standard Cobalt Solution—Dissolve 0·1000 g. of pure cobalt sponge in nitric acid and make up to 1 litre in a graduated flask

1 ml. ≡ 100 μg. Co

10 ml. of this solution are diluted to 100 ml. to give a solution such that

1 ml. ≡ 10 μg. Co

and 10 ml. of this second solution diluted to 100 ml. again to give a solution such that

1 ml. ≡ 1 μg. Co.

Calibration

Range I

Measure aliquots of standard cobalt solution equivalent to 0, 20, 50, 100, 150, 200, 250 and 300 μg. of cobalt

into a series of 100 ml. conical separating funnels, and add 1·0 ml. of hydrochloric acid and 20 ml. of sodium acetate solution to each. Shake, add 1·0 ml. of 2-nitroso-1-naphthol solution, shake again and allow to stand for 2 minutes. Add 20 ml. of benzene, shake for 30 seconds and allow to separate. Run off the aqueous phase and wash the benzene layer by shaking for 10–20 seconds with the following :—

(1) 10 ml. of hydrochloric acid.

(2) 10 ml. of water.

(3) 10 ml. of N sodium hydroxide.

(4) 10 ml. of water.

Reject all the aqueous washings and dilute the benzene phase to 50 ml. in a graduated flask. Filter through a dry 5·5 cm. No. 541 filter paper into a 1 cm spectrophotometer cell and measure the optical density at 530 mμ against benzene. Plot a calibration curve, subtracting the blank reading from all the others in order to make the line pass through the origin.

This graph had a slope such that 0·1 optical density was equivalent to 21·5 μg. of cobalt. The useful range of this graph was thus about 10 μg. to 300 μg. of cobalt. This range can be extended to 600 μg. by diluting to 100 ml. with benzene instead of 50 ml., or used to cover the range 8–120 μg. more accurately by measuring the original 20 ml. of benzene from a burette and not diluting further, as used in the lower range calibration curve.

Range II

Measure aliquots of standard cobalt solution equivalent to 0, 2, 5, 10, 15, 20, 25 and 30 μg. of cobalt into separating funnels and process as before. Measure the 20 ml. of benzene from a burette, however, and do not dilute to 50 ml. before measuring. Instead, filter on a dry 5·5 cm. No. 541 filter paper into a dry 4 cm. cell and measure the optical density at 530 mμ against benzene.

Again, plot a graph after subtracting the blank value. This graph had a slope such that 0·1 optical density was equivalent to 2·15 μg. cobalt and covered the range 1·0 to 30 μg.

Method

Weigh a 1 g. sample into a 150 ml. squat beaker and dissolve, without heating, in 25 ml. of hydrochloric acid and 5 ml. of nitric acid (Note 1). When dissolved, cool and dilute to 100 ml. in a graduated flask. Allow any residue of graphite, silica, etc., to settle and pipette a 10 ml. aliquot of the supernatant liquid into a 150 ml. conical separating funnel.

To the solution in the funnel, add 2·5 ml. of 6% cupferron solution for every 10 mg. of metals which will react with cupferron, and shake (Note 2). Add 30 ml. of chloroform, shake for 30 seconds and allow the two phases to separate. Rinse the stopper and neck of the funnel with chloroform from a polythene wash bottle in order to remove any particles of cupferrate adhering to them, and run off the chloroform layer. Check for completeness of precipitation by adding a few drops of cupferron solution to the funnel. A white precipitate of free N-nitroso-phenylhydroxylamine should be obtained (Note 3). If the precipitate is coloured, add a further 5 ml. of cupferron solution.

Add 10 ml. of chloroform, shake for 10–20 seconds and allow the phases to separate. Run off the chloroform layer and continue to wash with 10 ml. portions of chloroform until the chloroform layer is colourless. Reject all the chloroform extracts.

Pour the aqueous solution out of the neck of the funnel into a 150 ml. squat beaker in order to avoid contamination with the cupferrate residue in the funnel stem, and wash with water. Evaporate the solution to dryness and add 5·0 ml. of nitric acid and 3·0 ml. of perchloric acid from safety pipettes. Keeping the beaker covered with a well-fitting lid, evaporate to fumes of perchloric acid and fume for 3–5 minutes.

Cool, dilute with about 10 ml. of water and, if the solution is yellow or brown due to chromate or manganese dioxide, add solid hydroxylamine hydrochloride until the colour is discharged. Transfer to a 150 ml. separating funnel, adjust the volume to 20–30 ml. and add 25 ml. of 2 M sodium acetate solution.

Add 1·0 ml. of 1% 2-nitroso-1-naphthol solution for every 3 mg. or part of 3 mg. of nickel plus cobalt present (Note 4). Allow to stand for 2 minutes, and if a bulky precipitate is obtained, add 20 ml. of hydrochloric acid and allow to stand until the precipitate dissolves. Add 20·0 ml. of benzene from a burette, shake for 30 seconds and allow the phases to separate. Run off and reject the aqueous layer and wash the benzene phase with acid, water, alkali and water as for the calibration curves. Measure the optical density at 530 mμ in a volume of 20, 50 or 100 ml., using a cell size appropriate to the cobalt content. The following colours in the benzene phase may be taken as a guide to the amount of cobalt present :—

Very pale pink	— less than 15 μg.
Pink to red	— 20–100 μg.
Deep red	— over 100 μg.

Notes

(1) If the material contains appreciable amounts of niobium, tantalum, tungsten, titanium or zirconium, add 10 ml. of hydrofluoric acid to prevent hydrolysis.

If the sample does not dissolve readily, treat as appropriate. See under "Solution Techniques."

(2) According to Morrison and Freiser,[6] the metals reacting with cupferron in acid solution when dissolved under oxidising conditions are : bismuth, copper, indium, iron, molybdenum, niobium, tantalum, palladium, thorium, tin, titanium, tungsten, vanadium and zirconium.

If less than 5 mg. of iron plus copper are present, the cupferron extraction can be omitted ; to the 10 ml. aliquot, add 30 ml. of 2 M sodium acetate and 2-nitroso-1-naphthol. Sufficient 2-nitroso-1-naphthol must be added to react with the copper and iron as well as the nickel.

(3) Some cupferrates are white, but the elements which interfere with the cobalt determination, namely, copper and iron, give dark brown and blue extracts respectively. The elements whose cupferrates are white do not interfere.

(4) If the reagent is freshly purified, up to 40 ml. (equivalent to 100 mg. of nickel) can be used. If the reagent is more than 24 hours old, however, not more than 10 ml. (equivalent to 30 mg. of nickel) should be used. If more than 20 ml. is used, a second hydrochloric acid wash should be inserted before the water wash.

Acknowledgments

The author is indebted to Mr· B. Bagshawe, Chairman

of the B.I.S.R.A. Highly Alloyed Steels and Ferro-alloys Analysis Sub-Committee, for permission to use the B.I.S.R.A. samples and cobalt figures, and to Mr. W. Foster of The Wolverhampton and Staffordshire College of Technology, who carried out the infra-red examination of the residue from the blank solution. Thanks are also due to the Director and Council of the B.C.I.R.A. for permission to publish this work.

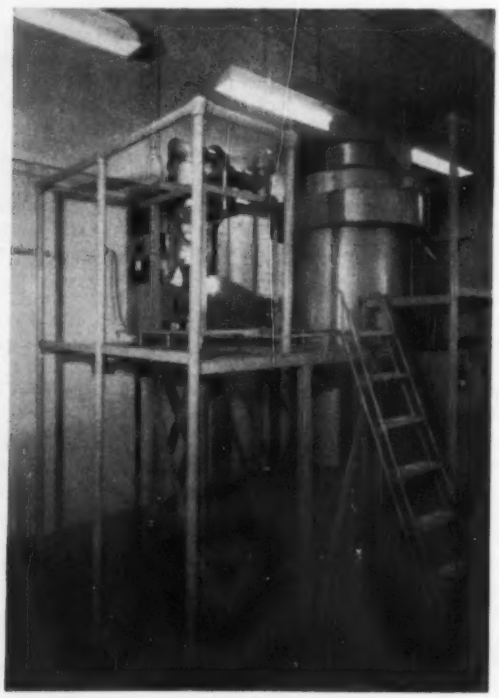
REFERENCES

1 Rooney, R. C., *Metallurgia*, 1958, **58**, 205–208.
2 Boyland, E., *Analyst*, 1946, **71**, 230–231.
3 Claasen, A., and Daamen, A., *Analytica Chimica Acta*, 1955, **12**, 547–553.
4 Westwood, W., and Mayer, A., "Chemical Analysis of Cast Iron and Foundry Materials," 2nd edition, 1960, London, Allen & Unwin, see esp. p. 38.
5 B.I.S.R.A. Methods of Analysis Committee, *J. Iron and Steel Inst.*, 1959, **191**, 236–240.
6 Morrison, G. H., and Freiser, H., "Solvent Extraction in Analytical Chemistry," 1957, London, Chapman and Hall, see esp. pp. 169–171.

A 'Tailor-Made' Vacuum Furnace Installation

APART from the design and development of vacuum furnaces, the metallurgical research laboratory of Edwards High Vacuum, Ltd., devotes an appreciable proportion of its efforts to the provision of pumping systems suitable for metallurgical work. The vacuum requirements of various metallurgical operations, such as melting, degassing, brazing and annealing, may be quite different as regards ultimate vacuum and quantities of gas to be handled, and these will govern the type of vacuum pump used.

An interesting example of a "tailor-made" pumping system is that supplied recently to Atomic Power Constructions, Ltd., for use in their Hounslow laboratories. The pumps in this case are fitted to a Royce electric furnace of the forced air circulation type, which is being used in connection with a fuel development programme The furnace is a standard unit and is equipped with fully automatic temperature control and temperature recording equipment. With a rating of 24 kW. on a 440 V., 3-phase, 50 c./s. supply, the maximum operating temperature is 400° C. The tube, which has internal dimensions of 9 in. diameter × 50 in. high was supplied complete with a top flange machined to mate with the connecting flange of the Speedivac pumping equipment.



Vacuum furnace installation at Atomic Power Constructions Ltd.

The pumping system comprises a Model 903 B oil diffusion pump having a peak speed of 1,500 litres/sec. and an ultimate vacuum of 5×10^{-6} torr, backed by a Model 1SC450 single stage air ballasted rotating pump. The diffusion pump is fitted with a 12R8 right-angle baffle valve which also serves to isolate the pump from the furnace system. It is necessary to be able to remove the tube from the furnace after heating, and at the same time retain the vacuum for a period. For this purpose a 6 in. bore water-cooled T-piece is provided to form a demountable connection between the baffle valve and the furnace tube. A QSB6 quarter-swing butterfly valve is used to seal the vacuum in the T-piece when it is disconnected from the pumping system. The furnace tube and the T-piece can be thus removed from the furnace without breaking the vacuum in the tube itself.

Vacuum measurement is provided by a combined Pirani-Penning vacuum gauge, the control unit being panel-mounted on the side of the pumping unit. The Penning gauge head is mounted in the water-cooled T-piece to indicate the vacuum in the furnace tube, whilst Pirani gauge heads are mounted in the backing line to indicate rough pressure. Hand-operated Speedivalves are used in the backing and by-passing lines.

The complete pumping outfit is mounted in an angle iron framework mounted on castors for mobility. Screw jacks are also provided to maintain rigidity whilst the unit is in use. One side of the framework is panelled to accommodate the Pirani-Penning control unit and the switch controls for the rotary and diffusion pumps.

Southern Analytical, Ltd.

THE analytical instrument activities of Southern Instruments, Ltd., will in future be carried out in the name of Southern Analytical, Ltd., a company newly formed for the purpose. Members of the board will include Mr. W. B. Horner (general manager), Mr. H. M. Davis (chief engineer), and Mr. J. A. Colls. The chairman is Mr. P. Sellars, vice-chairman of Southern Instruments, Ltd.

Optical Techniques Conference

A CONFERENCE on Optical Instruments and Techniques is being arranged by the British National Committee for Physics, under the auspices of the International Commission for Optics. It will be held in London during the period July 10th–14th, 1961. Enquiries should be addressed to Mr. K. J. Habell, National Physical Laboratory, Teddington, Middlesex, England.

Controlled furnace atmosphere & temperature with oil

COMBUSTORS

- ★ High temperature, high intensity flames
- ★ High or low excess air
- ★ Atmosphere control by re-circulation
- ★ Suppression of SO 3 formation
- ★ Complete absence of smoke & smut

COMBUSTOR OPERATION

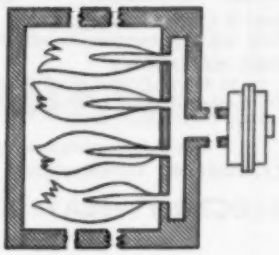
The stable toroidal flow pattern ensures cool refractory walls and highly pre-heated combustion air. The unusually high temperature prevailing in the pre-heated air/oil flame gives completely smoke-free, neutral or controlled oxidising products very near theoretical temperature.

GASIFICATION

Exceptionally fine atomisation combined with highly turbulent mixing and intense radiation provides a range of hot producer gases to choice, suitable for ducting to furnace ports.

AUTOMATIC CONTROL

Fully automatic control can be based on temperature, on atmosphere or on both. Burner systems have press-button ignition and there is a flame failure control on each burner.



GASIFIERS

- ★ Absolute control of furnace atmosphere
- ★ Soft, lazy radiant flames or completely combusted products
- ★ Any grade of fuel oil or coal tar fuel
- ★ Instantaneous response
- ★ Continuous operation

APPLICATIONS INCLUDE Melting and Re-heating Furnaces, Annealing Ovens, Core Stoves, Brick Driers etc. and the Auxiliary Firing of Waste Heat Boilers.

FOR FULL DETAILS WRITE

URQUHART'S (1926) LTD

5 Wadsworth Road, Perivale, Middlesex. Perivale 9511 ;
Albion Dockyard, Bristol, 1. Bristol 26221

THE

"SORTATIONER"

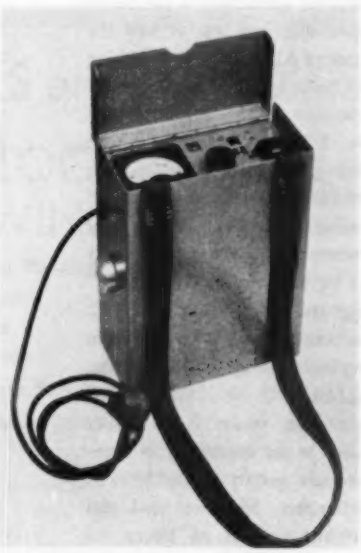
(BRITISH PATENT No. 833 203)
(WORLD PATENTS PENDING)

FOR INSTANTANEOUS SORTING AND TESTING OF NON FERROUS ALLOYS

VERY CHEAP

COMPLETELY PORTABLE

VERY ROBUST



It will operate with Aluminium, Magnesium or Copper alloys and will identify all of them if preset to appropriate standards.

It will test for correct heat treatment.

It will identify Aluminium Clad sheet and check annealing.

It will identify gold and its alloys, silver and its alloys and differentiate between Tantalum and Niobium.

A SPECIAL MODEL IS AVAILABLE FOR TITANIUM AND ITS ALLOYS

Ask for Leaflet M.234

TOWNSON & MERCER LIMITED

CROYDON THOrnton Heath 6262
EDINBURGH CALedonian 1410
OXFORD Oxford 41900

A.R.B., D.G.I., APPROVED

BRIGHT ANNEALING ● ***BRIGHT HARDENING***

Steel & Copper Pressings, Bolts, Strip and large components up to 4ft.

Bolts, Springs, and also large components up to 3ft.

CASE HARDENING up to 4ft. 6in. ● ***LIGHT ALLOYS***

Gas Carburizing, Carbo-nitriding, High Frequency, 10kVA

Solution and Precipitation up to 10ft.

Selected controlled atmospheres for all purposes

LABORATORY SUPERVISION ● ***LOCAL DELIVERIES***

ELECTRO HEAT TREATMENTS LTD.,

Bull Lane, WEST BROMWICH, Staffs.

Telephone No. Wes. 0584 - 0756

FOR ALL TYPES OF

HEAT TREATMENT

CONSULT

ABBEY HEAT TREATMENTS LTD.

(A.I.D., Min. of Supply and other Govt. Depts.)

PLAZA WORKS, MERTON HIGH STREET LONDON, S.W.19

Phone: CHErrywood 2291/2

We collect and deliver in the London area

BLACKWELLS FOR ALLOYS

SILICON • MANGANESE • ALUMINIUM

NICKEL • NICKEL ALUMINIUM • BORON

TITANIUM • CHROMIUM • RUTILE • COPPER

Since 1869 Blackwells have been recognised pioneers in Metallurgical development.

Their Technical Advisory service is unique, and your enquiries on your particular problems are invited. Get in touch today with :—

BLACKWELLS METALLURGICAL WORKS LTD.

Thermetal House, Garston, Liverpool 19

'Phone : Garston 980 'Grams : "Blackwell," Liverpool

Efficient quenching is controlled quenching and that is why the usage of ALMARINE quenching oils backs up the experience of the operator. Take ALMARINE No. 2 Grade for example, with flash test figures that indicate absolute safety, it gives a rapid cooling rate immediately after immersion, cools more slowly during the so-called "tempering" stage and very slowly after 400°C. has been reached. Where the main emphasis is on cyanide-hardening, ALMARINE No. 3 Grade is just as reliable, whilst it is equally suited to the quenching of case-hardened parts produced by solid carburisers. May we send you further details of these oil quenching media?

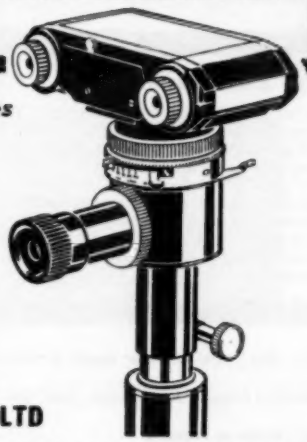
FLETCHER MILLER QUENCHING OILS

FLETCHER MILLER LTD . ALMA MILLS . HYDE . CHESHIRE

Telephone : HYDE 3471 (5 lines) Telegrams : EMULSION, HYDE

H T 3

ATTACHMENT CAMERA for PHOTOMICROGRAPHY



35 mm. or plates

* Versatility
* Speed
* Quality

R. & J. BECK LTD

69/71 MORTIMER ST · LONDON W. 1

Pre-eminent for more than a century

THOMAS ANDREWS

and COMPANY LIMITED

HIGH-GRADE STEEL MAKERS

"MONARCH" { HIGH SPEED STEELS / HOT & COLD DIE STEELS / TOOL HOLDER BITS

"HARDENITE" { CARBON & ALLOY TOOL STEELS for ALL PURPOSES

"HELVE" { CARBON TOOL STEEL for CHISELS, PUNCHES, &c.

ROYDS WORKS AND
HARDENITE STEEL WORKS
ATTERCLIFFE ROAD, SHEFFIELD.

Export Department
THE HARDENITE STEEL COMPANY LIMITED

Telephone
SHEFFIELD 22131

Telegrams
SHAFTING, SHEFFIELD, 4

ALLOYS for STEELMAKING

Ferro Tungsten 80/85%
Ferro Vanadium 35/80%
Ferro Molybdenum 70/75%
Calcium Molybdate 40/50%
Molybdenum Briquettes 55/65%
Ferro Titanium 20/25% and 40%
Tungsten Metal Powder 98/99%
Manganese Metal
Chromium Metal

METALS and POWDERS for TOOL TIPS DRAWING DIES, Etc.

Tungsten Metal Powder
Tungsten Carbide
Tungstic Oxide
Titanium Carbide
Ammonium Para Tungstate
and other metallic carbides

Our specification booklet, giving full details of all our products and our quarterly ALLOY Metals Review, will be gladly sent on request to us at :— DITTON ROAD, WIDNES, LANCASHIRE

HIGH SPEED STEEL ALLOYS LTD.

Ditton Road, Widnes, Lancashire

Telegrams : ALLOY, WIDNES

Telephone : Widnes 2661

have you a problem to do with metal preparation, rust removal or corrosion prevention?
YOU HAVE? then read on....

FERRIC SULPHATE

As a pickling agent results in rapid, clean and fume free method of descaling stainless steel, copper and brass and an improved method of etching mild steel surfaces prior to coating. Non-fuming, non-toxic, safely handled. Full technical details available on application.

WESTOLITE Rust Remover

This is supplied in two forms: liquid and thixotropic. The former is recommended for dipping batches of ferrous metal goods. It is a particularly efficient phosphating material which combines effectively with the surface metal to produce a protective non-rusting layer. Thixotropic Westolite has been developed for use on industrial plant, structural steelwork, and in situations where immersion is precluded. In the form of a gell, Thixotropic Westolite becomes temporarily free-flowing when applied with a brush but after application resumes its paste-like consistency. Advantages include, adherence to vertical surfaces, no drips and no wastage. Technical details available on application.

TECHNICAL ADVISORY SERVICE

E. & A. WEST LTD., can provide the answer to most problems relating to the preparation of metal surfaces, rust removal and corrosion prevention. Our Technical Advisory Service is at the disposal of industry and will be glad to get to grips with your particular problem. The answer may even be in their impressive library of "case histories", so do not hesitate to call them in. The service is quite free and non-obligatory.

E. & A. WEST LTD. also manufacture or supply a whole range of industrial chemicals including Dipping Acid, Nitric Acid, and Hydrofluoric Acid. Full details on request.

E. & A. WEST LIMITED.,

Parcel Terrace, Derby. ***Telephone: Derby 45008.***

WEST
CHEMICALS FOR INDUSTRY

BOLTON'S

HIGH TENSILE BARS up to 4½" diameter.

ROLLED AND MACHINED BARS up to 6" diameter.

WIRE in all sizes from 0.0076" diameter upwards.

STRAND. **SHEETS** up to 6ft. x 3ft. x $\frac{1}{16}$in. diameter upwards. **STRIP AND FOIL**

DRAWN SECTIONS **MACHINED PARTS** **NUTS AND BOLTS**

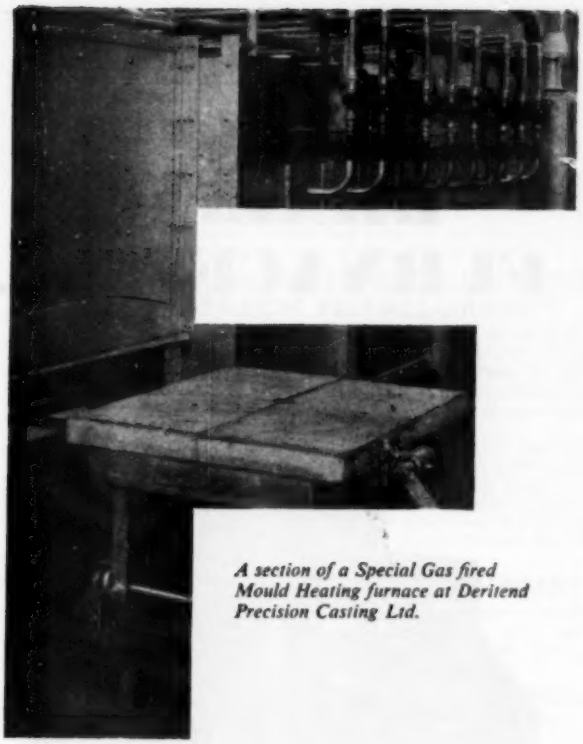
THOMAS BOLTON & SONS LTD

Head Office: Mersey Copper Works, Widnes, Lancashire. Telephone: Widnes 2022

London Office & Export Sales Department: 168 Regent St., W.I. Tel.: REGent 6427

THOMAS BOLTON & SONS LTD

CVS-55a



A section of a Special Gas fired Mould Heating furnace at Deritend Precision Casting Ltd.

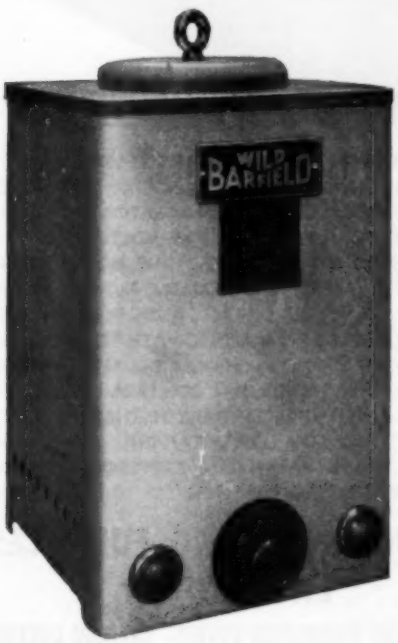
FRANKLIN FURNACES

There's big savings in terms of dependability and easy maintenance when Franklin are called in on that furnace installation. Long experience in the supply of standard, and the design of special furnaces mean the snags are quickly ironed out. Furnaces fired by 'Dine' Burners give easy maintenance and fuel economy, that's why more and more well-known Companies are now counted as customers.
Our team of experts would welcome the chance to look into your furnace problems.

FRANKLIN

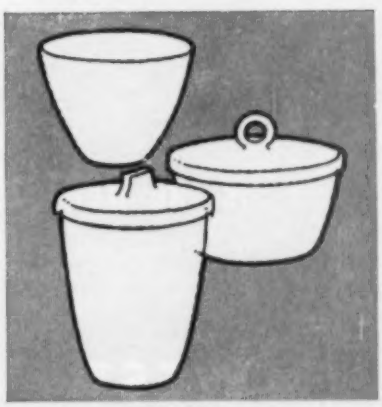
MANUFACTURERS OF INDUSTRIAL FURNACES AND OIL BURNING EQUIPMENT FOR ALL PURPOSES

FRANKLIN FURNACE CO. LTD., BAKER STREET, SPARKHILL, BIRMINGHAM 11, ENGLAND



Wild-Barfield muffles for a better job

These small self-contained vertical crucible muffles are ideally suited for many purposes in the average laboratory or research department. Chamber size and maximum temperature alone dictating the limits of their usefulness. Standard models have a maximum operating temperature of 1050°C (1922°F), and are complete with energy regulator type hand temperature controller and pilot lights.

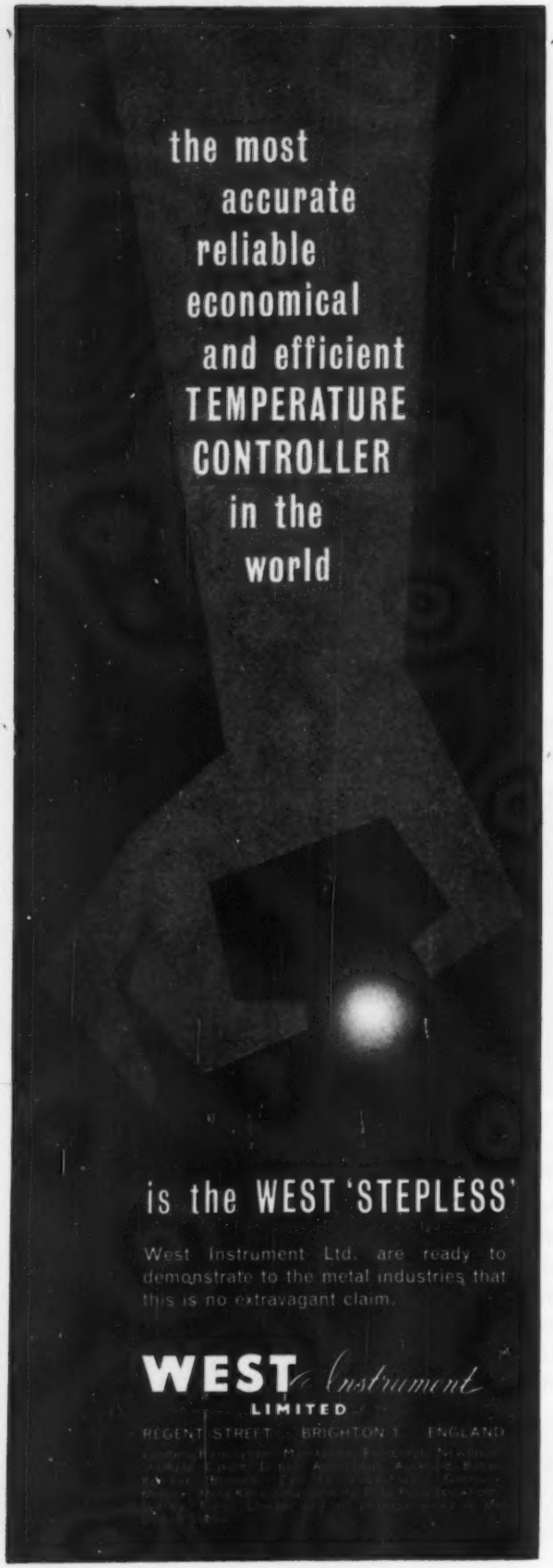


ELECTRIC WILD BARFIELD FURNACES

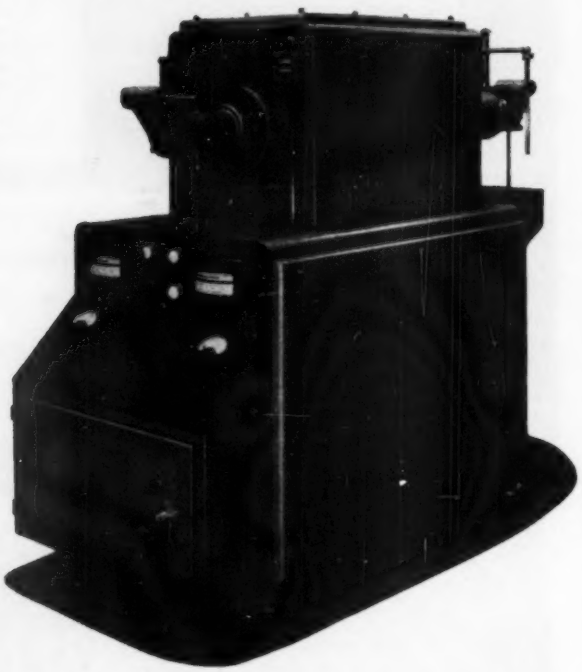
for all *heat treatment purposes*

WILD-BARFIELD ELECTRIC FURNACES LIMITED

ELECFURN WORKS, OTTERSPOOL WAY, WATFORD BY-PASS, WATFORD, HERTS. Tel: Watford 26091 (9 lines) Grams: Elecfurn, Watford. WB1GW



SINTERING and BRAZING FURNACES Ltd.



● THE ILLUSTRATION SHOWS A MOLYBDENUM HIGH TEMPERATURE FURNACE WITH A RANGE UP TO 1700°C. THE ELECTRICAL SUPPLY IS FED VIA AN ISOLATOR SWITCH TO THE AIR-COOLED TRANSFORMERS. THE VOLTAGE OF THE SECONDARY WINDINGS WHICH FEED THE MOLYBDENUM WOUND HEATING ELEMENTS IS VARIABLE FROM 10 VOLTS UPWARDS BY MEANS OF COARSE AND FINE TAPPING SWITCHES. THE FURNACE IS EQUIPPED WITH TEMPERATURE CONTROLLERS AND UPON REACHING A DESIRED TEMPERATURE, A DEGREE OF PROPORTIONAL CONTROL IS ATTAINED BY THE VOLTAGE OF THE SECONDARY FEED BEING AUTOMATICALLY SWITCHED TO A LOWER TAPPING. AUTOMATIC DOOR GAS FLOODING VALVES ARE CONTROLLED VIA A MAGNETIC SOLENOID MECHANISM.

SINTERING & BRAZING FURNACES LIMITED

HEAD OFFICE 124a/130 EDINBURGH AVENUE, TRADING ESTATE, SLOUGH, BUCKS.

TELE: SLOUGH 21143 GRAMS: SINTBRAZ SLOUGH

WORKS: 183 LIVERPOOL ROAD, TRADING ESTATE, SLOUGH.

Opportunities in

Research

Steel Company of Wales production continues to increase. Tonnages are up to 3 Million per annum and new plant now under construction will raise output even further—to another 500,000 tons a year.
This rapid expansion creates new posts in the Company's Steel Division for high calibre Research Officers :—

SENIOR RESEARCH METALLURGISTS AND RESEARCH METALLURGISTS

to conduct research in the laboratories and in the Plant.

Laboratory work is primarily concerned with the properties of low carbon steel sheet and includes the assessment of formability, surface properties and treatment and the effect of production processes on such properties. A substantial part of our research concerns the development and evaluation of new materials.

The Company's Research Metallurgists are also concerned with the application of laboratory techniques such as X-ray crystallography and vacuum fusion to assist allied plant research work.

Plant research includes metallurgical studies of sinter plant and blast furnace operations—including the operation of a pilot sinter plant—the investigation of refining processes in open hearth and Bessemer furnaces and the metallurgy of hot strip mills.

ASSISTANT PLANT METALLURGISTS

Metallurgists or Metallurgical Engineers are required to assist in the examination of engineering failures. This work includes short-term projects to establish the most suitable materials for a variety of service conditions in a large steelworks.

QUALITY CONTROL METALLURGISTS

to work in close collaboration with Plant Management in maintaining and improving standard of quality. Work ranges from experiments in the works to Technical service of products at customers' plant.

Problems must be solved quickly and the accent is on practical results.

SUPERINTENDENT, PERSONNEL SERVICES
THE STEEL COMPANY OF WALES LIMITED
(*Steel Division*)
Abbey Works, Port Talbot, Glam.

ENV

facilities for HEAT TREATMENT

The ENV heat treatment plant is one of the most modern and comprehensively equipped in the London area.
Facilities include full metallurgical control, quenching press equipment and electrically controlled flame hardening machine.
Enquiries for heat treatment of production quantities are invited.

E.N.V. ENGINEERING CO. LTD
HYTHE ROAD, WILLESDEN, N.W.10
TELEPHONE: LADbroke 3622

AP 112

GRADUATE
FOR POST IN GROUP RESEARCH AND DEVELOPMENT LABORATORY
For work on a variety of problems in the field of Ferrous Metallurgy. Excellent opportunity for gaining a wid experience of works practice. Minimum qualifications, degree in Metallurgy. Details of qualifications and experience to :—Research Manager, Bradley and Foster Ltd., Darlaston Iron Works, Darlaston.

MINISTRY OF AVIATION, Inspectorate of Fighting Vehicles and Mechanical Equipment, Kidbrooke, London, S.E.3, require CHEMIST III to assist in technical control and preparation of inspection techniques relating to protective treatment systems applicable to ferrous and non-ferrous metals used in bridging and vehicle construction. Quals.: Degree in Chemistry or Associateship of Royal Institute of Chemistry or Institution of Metallurgists or equivalent with experience in dealing with corrosion problems, painting systems and metal spraying. Knowledge of plastics an advantage. Salary : £805 (age 25)–£1,260 p.a. (National scale plus London weighting). Age 34 or over start at £1,095. Forms from Ministry of Labour, Technical and Scientific Register (K), 26 King Street, London, S.W.1, quoting reference F.616/OA. Closing date 14 October, 1960.

MINISTRY OF AVIATION requires TECHNICIAN at Harefield, Middlesex, for the physical testing of metallic materials including determination of fatigue properties and the evaluation of elastic properties at widely different straining rates and at normal and elevated temperatures. Development of new techniques is an important feature of the duties. *Quals. :* Recognised eng. apprenticeship. ONC., C. and G. Final Certs. or equiv. qual. in Metallurgy. Experience in mechanical testing is essential. *Salary :* £975–£1,115. Application forms from Manager (P.E.2921), Ministry of Labour, Professional and Executive Register, Atlantic House, Farringdon Street, London, E.C.4.

AEI

ASSOCIATED ELECTRICAL INDUSTRIES LTD.
RESEARCH LABORATORY
HARLOW, ESSEX

METALLURGISTS

required for interesting and progressive posts in a new laboratory situated in the green belt, but only 40 mins. from London.

If you have metallurgical training you are invited to join a recently formed and expanding team engaged in the long term and applied research of a wide range of metallic materials for the electronics, cable and telecommunications industry.

Adequate recognition will be given for initiative, responsibility and plain hard work. We can offer a first class salary, and housing is available on appointment. This is an opportunity you are advised to investigate.

Please write to :—

Dr. J. E. Hughes,
Metallurgy Section,
A.E.I. (Woolwich) Ltd.,
Research Laboratory,
West Road, Temple Fields,
Harlow, Essex.

CLASSIFIED ADVERTISEMENTS

RADIOLOGICAL TECHNIQUES

An EXPERIMENTALIST is required at

ATOMIC ENERGY RESEARCH ESTABLISHMENT, HARWELL

to assist in development of special radiological techniques as a member of a team studying new methods of materials inspection. *The work does not involve routine radiography.*

Applicants should have G.C.E. at "A" level H.N.C. or equivalent. Practical experience of radiography is required as a basis for more specialised studies and experience in gamma radiography, autoradiography or counting techniques would be an advantage.

SALARY: £605 (at age 21)—£1,005 p.a.

Housing assistance and superannuation schemes.

Send POST CARD for details to Personnel Manager (1769/126) U.K.A.E.A., A.E.R.E. Harwell, Didcot, Berks.

Applications are invited for the post of

DIRECTOR

of the newly formed

DROP FORGING RESEARCH ASSOCIATION

The Association, which will be independent, will operate at the B.I.S.R.A. Laboratories at Hoyle Street, Sheffield. A highly qualified scientist is sought, preferably with previous experience in Research Association work, who can build up and lead a new Research Organisation. The salary, which will be substantial, will be commensurate with qualifications and experience.

Applications, which will be dealt with in strict confidence, should be sent with full particulars to A. L. Stuart Todd, Secretary, Drop Forging Research Association, 245, Grove Lane, Handsworth, Birmingham 20.

IMPERIAL SMELTING

U.K. MEMBER OF THE CONSOLIDATED ZINC CORPORATION LIMITED

MATERIALS ENGINEER

This is a new post with Consolidated Zinc Corporation (Sales) Ltd., for a man over the age of 25 possessing a good personality and with professional, engineering or metallurgical qualifications and conversant with the problems of nuclear power generation. Honours degree is preferred but the main requirement is a thorough knowledge of the engineering applications of materials and the ability to promote sales of beryllium and its alloys. A knowledge of the engineering requirements in the aeroplane structure, guided missile and guided system fields would be an advantage. MTE/M.

Applications for the above vacancy giving brief details of qualifications and experience should be addressed to :—

CZC

Personnel Manager,
Imperial Smelting Corporation Ltd.,
St. Andrew's Road,
Avonmouth.

SITUATIONS VACANT

METALLURGIST for development work on non-ferrous tube manufacturing processes. Good prospects for man with energy and drive. Midlands area. Write giving details of qualifications and previous experience to Box No. MY97.

UNIVERSITY OF OTAGO
Dunedin, New Zealand

LECTURER IN METALLURGY

Applications are invited for the above-mentioned position in the Faculty of Technology.

Salary range £1,250 × £75—£1,700 p.a.

Further particulars and information as to the method of application are available from the Secretary, Association of Universities of the British Commonwealth, 36 Gordon Square, London, W.C.1, or from the Registrar, University of Otago, Dunedin, New Zealand.

Applications close, in New Zealand and London, on November 30th, 1960.

METALLURGIST required for Research and Development by Company whose activities include the manufacture of hard metal cutting tool alloys, refractory alloys, sintered tungsten alloys, and ceramics. Excellent working conditions in modern, well equipped Laboratories. Opportunity given for occasional travel abroad to visit associated Companies.

Applicants should be between 22 and 30 years of age and have a University degree or equivalent qualification. Previous research experience not essential. Excellent Superannuation and Life Assurance Scheme in operation. Midlands area (Warwickshire). Apply in confidence, stating age, qualifications and experience to Box No. MY98, "Metallurgia," 31, King Street West, Manchester 3.

SPICER'S ZIRCONITE
MACHINABLE REFRACTORY

- SOLVES A LOT OF PROBLEMS
- SAVES A LOT OF TIME

Machinable Aluminium now available

W. & C. Spicer Ltd., The Grange, Kingham, Oxon.
TELEPHONE: KINGHAM 307

METALLOGRAPHIC MOUNTING MEDIUM

N.H.P. Mounting Plastic, a cold-curing acrylic resin, permits the rapid mounting of metallographic specimens without the aid of heat or pressure.

It calls for the minimum of equipment and skilled attention and yet gives a close, tight mount, capable of a high degree of edge preparation.

Used routinely by many leading manufacturers. Full details on request to the makers: NORTH HILL PLASTICS, LTD. MANLEY COURT, LONDON, N.16.

MSL *have been retained to advise on the appointment of a*

FOUNDRY MANAGER

to take charge of the production programme of a company in Ireland. The foundry employs fifty people and is being progressively mechanised, and it would be the responsibility of the Manager to apply effective supervisory and technical methods so as to ensure efficient and profitable growth.

Applicants must be practical furnacemen and moulders with a minimum of five years' experience on production of carbon and alloy steels (including austenitic manganese), operating electric arc furnaces with hand and machine moulding. Experience in the operation of side-blown converters would be advantageous.

Salary £2,000 per annum, plus non contributory pension, and removal expenses from the United Kingdom. Please send brief details in confidence quoting reference GR.2618 to D. S. A. E. Jessop.

MANAGEMENT SELECTION LIMITED, 17 Stratton Street, London, W.1.

In no circumstances will a candidate's identity be disclosed to our client unless he gives permission after a confidential interview at which he will be given full details of the appointment.

ATOMIC ENERGY RESEARCH ESTABLISHMENT, HARWELL

the newly formed

SOLID STATE PHYSICS DIVISION

will carry out experimental research into the physical properties of crystals including metals, alloys and ionic materials, using the special neutron diffraction and irradiation facilities provided by the research reactors, as well as a wide range of more conventional techniques.

Vacancies for both scientific and experimental officer grades exist in two types of work :—

(i) a small section to be set up for the development of methods for *producing extremely pure materials, principally of metals and alloys*, and for their subsequent examination, handling and fabrication into single crystal and other forms, before being used in one or more of the Division's physical investigations. The work will involve a wide range of experimental techniques including levitation, zone melting and metallographic and X-ray investigations and experience of this work would be an advantage. The work provides an excellent opportunity to extend to metals many of the techniques applied to semi-conductors.

One vacancy is for the section leader.

(ii) The neutron diffraction groups in which work is carried out on crystal spectrometers and on time of flight equipment, using neutrons from the high flux research reactors DIDO and PLUTO. Experience in modern laboratory techniques or in solid state physics would be an advantage, but full training will be available.

GRADUATES with a 1st or good 2nd class Honours degree with considerable experience will be considered for appointment as Principal Scientific Officer (£1,740–£2,460 p.a.) or Senior Scientific Officer (£1,365–£1,675 p.a.). Those with less experience will be considered for Scientific Officer posts : 3 years satisfactory post-graduate experience will attract a minimum salary of £960.

GRADUATES with a pass degree, or applicants with H.N.C., G.C.E. at "A" level or equivalent, are required to assist in the above work and will be considered according to age and experience for appointment as Experimental Officer (£1,100–£1,370 p.a.) or Assistant Experimental Officer (£605 (at age 21)—£1,005 p.a.).

Housing and superannuation schemes.

Send POST CARD for details to the Personnel Manager (1804/126), U.K.A.E.A.A.E.R.E., Harwell, Didcot, Berks.

MULLARD RESEARCH LABORATORIES

invite

applications from suitably qualified candidates for research work within their Solid State Physics Division under the following categories :

METALLURGISTS

Metallurgists are required for interesting research work on the physical metallurgy of semi-conductors. The work includes the study of the physical properties of near perfect single crystals of germanium and silicon and the metallurgy of unusual semi-conducting compounds.

Candidates should hold, or be studying for, a degree or H.N.C. in Metallurgy or Physics.

ASSISTANT METALLURGIST

An Assistant Metallurgist is required for service laboratory dealing with interesting metallurgical problems associated with semi-conductor devices, semi-conducting compounds, electro plating and electronic tube materials, etc.

Candidates should have a minimum qualification of O.N.C. in Metallurgy with some experience of metallography.

Successful candidates for the above posts are assured of excellent prospects of advancement in an important field of activity undertaken in a new modern laboratory fully equipped with up-to-date apparatus and situated in pleasant surroundings in the Surrey countryside 25 miles south of London.

Good salaries and conditions of service are available, including superannuation and life assurance schemes.

Applications should be addressed to Mr. G. A. Taylor, Mullard Research Laboratories, Cross Oak Lane, Salfords, near Redhill, Surrey.

METALLURGY

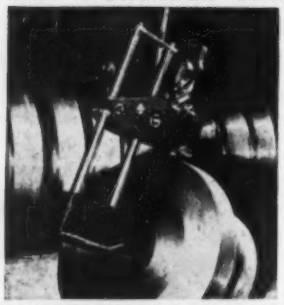
ANALYTICAL CHEMIST, aged 23–27 years required for Metallurgical Laboratory, Surrey/Middlesex border. Experience of fuels analysis an advantage as appointee will be required to assist in establishing a fuels testing laboratory. Minimum qualification is O.N.C. Write to : Staff Manager, Foster Wheeler Limited, 3 Ixworth Place, London, S.W.3.

METALLURGIST, degree or equivalent, for applied research and development work on metallurgical aspects of ferrous hot working processes. Expanding activity with scope for advancement. Please apply to The Director, Tube Investments Technological Centre, The Airport, Walsall.

INDEX TO ADVERTISERS

	Page
Abbey Heat Treatment, Ltd.	50
A.E.I. Birlec, Ltd.	45
A.E.I. (Manchester), Ltd.	—
Andrews, Thomas & Co., Ltd.	51
Baker Platinum	32
Baldwin Instruments, Ltd.	28
Beck, R. & J., Ltd.	51
Birkett, Billington & Newton, Ltd.	—
Birmingham Aluminium Castings, Ltd.	—
Blackwells Metallurgical Works, Ltd.	50
Bolton, Thomas & Sons, Ltd.	52
Bonnybridge Silica & Fireclay, Ltd.	44
Bradley and Foster, Ltd.	20
Brayshaw Furnaces, Ltd.	—
British Acheson Electrodes, Ltd.	8
British Driver-Harris & Co., Ltd.	3
British Electrical Development Assoc.	47
British Electrical Repairs, Ltd.	—
British Furnaces, Ltd.	10
Burton Griffiths & Co., Ltd.	—
Brown, David, Industries, Ltd.	19
Carborundum Co., Ltd., The	—
Cronite Foundry, Ltd.	29
Denison Samuel & Sons, Ltd.	—
Dowson and Mason, Ltd.	6
Dunford & Elliot, Ltd.	22
Edwards High Vacuum, Ltd.	34
Electro Heat Treatments, Ltd.	50
Electric Resistance Furnace Co., Ltd.	40
Elgar Trading Co.	—
E.N.V. Engineering Co., Ltd.	55
Engelhard Industries, Ltd.	32
Emmott, & Co., Ltd.	—
Firth, Thomas & John Brown, Ltd.	—
Fletcher Miller, Ltd.	50
Foundry Suppliers, Ltd.	58
Franklin Furnace Co., Ltd.	53
Fuel Furnaces, Ltd.	Inside Front Cover
Furnace Construction Co., Ltd.	30
Gas Council, The	—
G.E.C., Furnace Div.	Inside Back Cover
Gibbons (Dudley), Ltd.	—
G.W.B. Furnaces, Ltd.	26
Hale & Hale (Tipton) Ltd.	Front Cover
Hallamshire Steel Co., Ltd.	—
High Speed Steel Alloys, Ltd.	51
Hilger & Watts, Ltd.	—
Holroyd, John, & Co., Ltd.	Back Cover
Honeywell Controls, Ltd.	1
Ilford, Ltd., (Industrial X-ray)	11
Imperial Chemical Industries, Ltd.	43
Incandescent Heat Co., Ltd., The	31
Instron, Ltd.	37
Integra Leeds & Northrup, Ltd.	46
Ipsen Industries, Inc.	—
Jackman, J. W., & Co., Ltd.	23
Kasenit, Ltd.	7
Kent, George, Ltd.	48
Kingscliffe, Insulating Products	18
Lucas Furnaces, Ltd.	38
Marshall, Thomas, Ltd.	—
Mond Nickel Co., Ltd., The	16
Morgan Refractories, Ltd.	15
Newnes, George, Ltd.	—
Newton Chambers & Co., Ltd.	39
Pearson, E. J. & J., Ltd.	30
Pickford-Holland & Co., Ltd.	25
Priest Furnaces, Ltd.	13
Research & Control Instruments, Ltd.	—
Shell Mex and B.P. Gases, Ltd.	35
Sintering & Brazing Furnaces, Ltd.	54
Smethwick Drop Forgings, Ltd.	5
Southern Instruments, Ltd.	33
Stein, J. G., & Co., Ltd.	12
Sterling Furnaces, Ltd.	4
Stillite Products, Ltd.	27
Stordy Engineering, Ltd.	2
Thermal Syndicate, Ltd.	9
Thermic Equipment and Eng'g Co., Ltd.	14
Townson & Mercer Ltd.	49
Universal Diamond Co., Ltd.	6
Urquhart's (1926) Ltd.	49
Wellman Smith Owen Eng. Corpn., Ltd.	42
West, E. & A., Ltd.	52
West Instrument, Ltd.	54
Wiggin, Henry, & Co., Ltd.	24
Wild-Barfield Electric Furnaces, Ltd.	17, 21, 53
Williams, J., of Cardiff, Ltd.	—
Wincott, G. P., Ltd.	36
Yorkshire Testing Works, Ltd.	—

KING PORTABLE BRINELL HARDNESS TESTER FOR LOADS UP TO 3,000 KILOS, BY



KING TESTER CORP.
PHILADELPHIA U.S.A.

❖

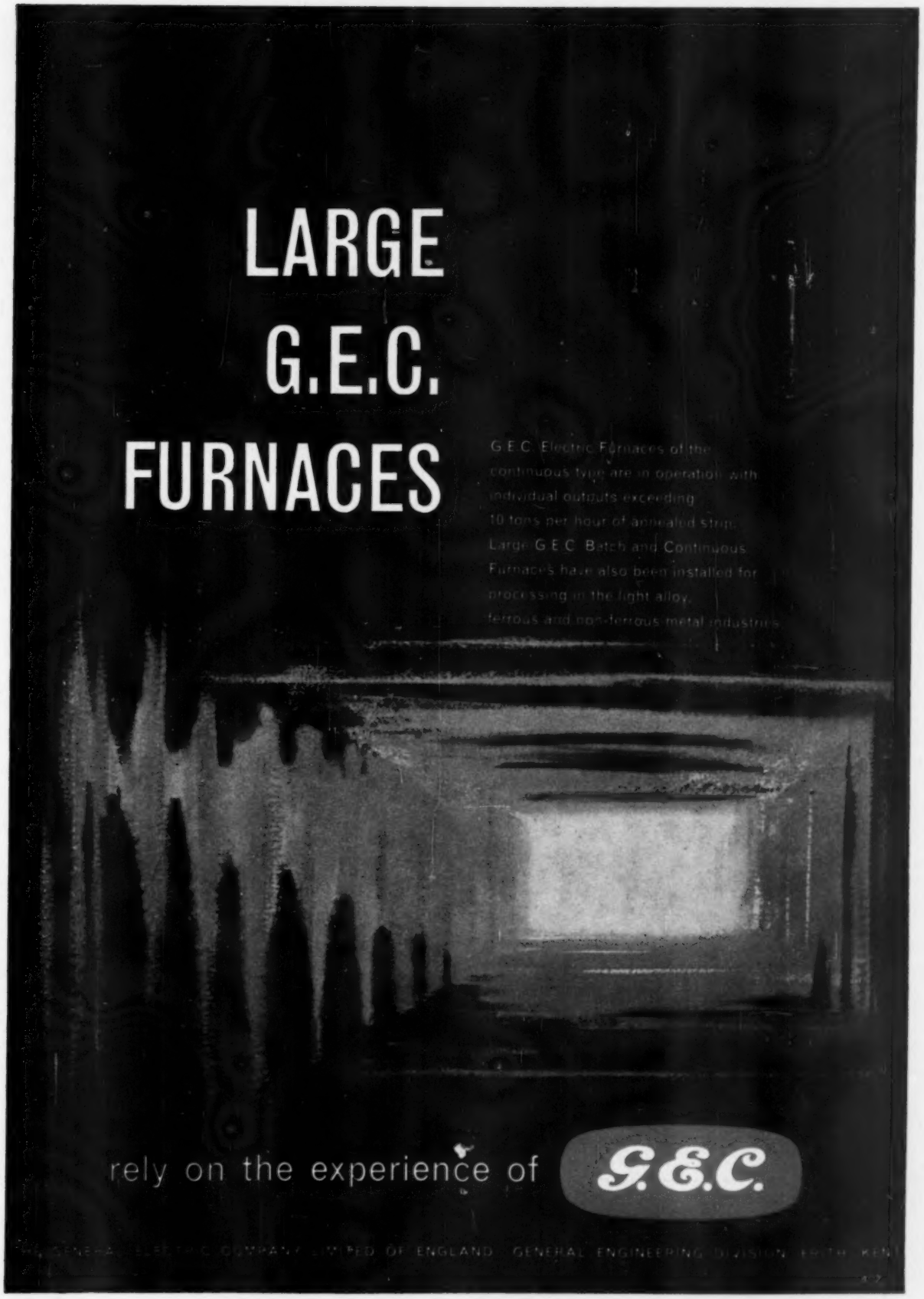
In any position anywhere the King Portable is Always Accurate

❖

FREE demonstration at your works on request

FOUNDRY SUPPLIERS LTD., 25A, COCKSPUR STREET, LONDON, S.W.1. **Phone: TRA 1141**

Printed for the Proprietors, The Kennedy Press, Limited, 31, King Street West, Manchester, 3, 158, Temple Chambers, Temple Avenue, London, E.C.4, by Percy Brothers, Limited, The Hotspur Press, Manchester 1 and London. Registered for transmission by Magazine Post to Canada and Newfoundland.


LARGE
G.E.C.
FURNACES
G E C Electric Furnaces of the continuous type are in operation with individual outputs exceeding 10 tons per hour of annealed strip. Large G E C Batch and Continuous Furnaces have also been installed for processing in the light alloy, ferrous and non-ferrous metal industries
rely on the experience of
G.E.C.
THE GENERAL ELECTRIC COMPANY LIMITED OF ENGLAND GENERAL ENGINEERING DIVISION ERITH KENT

Holfos Bronze
Regd.
—to increase your production
Ask for our Technical
Representative to discuss
the application of Shellcasting to your requirements
John Holroyd & Co. Ltd
P.O. BOX 24, HOLFOS WORKS, ROCHDALE, LANCS. Tel. 3155
BRONZE · GEARS · MACHINE TOOLS